BELLEVISTAT

Bellevistat

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1.EXECUTIVE SUMMARY

"It's a dangerous business, Frodo, going out your door. You step onto the road, and if you don't keep your feet, there's no knowing where you might be swept off to."

- J.R.R. Tolkien

Technology. It has been, and will always be, a tacit expression of human scientific progress. It is the junction of the pragmatic nature of investigation and the romanticism of a very inherent and visceral sense of curiosity. But, alas, this most defining of all human achievements has proven to be a fickle ally. Ever since we first conquered the African plains tens of thousands of years ago, the evolution of our technology has outpaced us. Whether we painstakingly analyze the progress of technology from start to finish or simply cut from our first weapon made of bone to an orbital weapons platform in a single, elegant shot, the underlying theme is clear. Never before in our history have we made so many advances in so short a timespan. When we first stepped out our door as a humble primate, we had no idea where on Earth our journey down the path of innovation would take us. We have since made many impressive strides down this path, but once again we stand, introspective, wondering where it will take us next. One thing is for sure though: it will most certainly not be on Earth.

Our intimate relationship with our technology has told a story not only of innovation but also of conquest. It took centuries to conquer the oceans, yet only decades to reign king over the skies. Just recently, we have taken our nascent steps into outer space, and without a doubt this wide expanse will become ours as well. Yet how will we accomplish this? Now that we have begun to escape the confines of our increasingly crowded world, where will our technology take us from here? As Tolkien wisely said, there is no knowing where we might be swept off to, so this project will present our own humble vision of our future in space; the natural expansion of our influence; the technological innovation of our most vivid imaginations.

We at Northdonning Heedwell are proud to present our own revolutionary proposal for the next stage of human technological evolution in space. Our space settlement, Bellevistat, is an orbital station which will be located at the Earth-Moon L4 Lagrangian point. The settlement will be developed in an entirely modular design, maximizing efficiency and allowing people to start their new lives onboard is the quickest way possible. Bellevistat consists of a series of concentric segmented rings, with both rotating and non-rotating components. Bellevistat features extensive occupational area, from habitation rings at different stages of gravity to outer zero-gravity segments. A powerful support structure unifies the full design into a simultaneously aesthetic and effective tour de force. With a strong focus on safety, all modules of Bellevistat will be created in such a way that they can be isolated in the event of an emergency, be it a hull breach, fire, gas leak, etc.

Bellevistat will be the operational hub for simultaneous mining and refinement missions on both Near-Earth Asteroids as well as the surface of the moon. These operations will begin

before Bellevistat has even been constructed in order to create the necessary materials for construction, freeing the company from total dependence on materials from the Earth. This approach cuts down overall costs significantly while establishing a thriving mining business for Bellevistat that will return massive profits later on once the materials can start being sold to other companies.

In addition to the mining enterprise, Bellevistat will play host to the largest manufacturing operation for buckystructures in space. Several zero-gravity segments will be devoted to the materials research and manufacturing machinery required to create high quality buckystructures of different types to suit the needs of modern construction. Also, Bellevistat's position at Earth-Moon L4 allows is to be a critical station within cis-lunar space. Bellevistat will serve as a major trading hub within the solar system, with an extensive station wide docking system in place to carry shipments of materials and goods as well as people.

We are thrilled by the prospect of building our vision for the future, Bellevistat, and wait eagerly for your consideration so that we may begin the long path that will lead to our species's greatest achievement. Until then, let us continue to journey farther out down this long path. Let us face the challenges of tomorrow head-on, with ingenuity and humility as our guides. Let us venture as far as our imaginations can take us, soaring to new heights and achieving ever loftier goals. And last but not least, let us be swept off to exciting new lands forged by man in the vacuum of space. For home is behind, the Universe ahead, and there are many paths to tread.

2. STRUCTURAL DESIGN

SPACE ALLOCATION

A total area of 300 square meters per person is ideal to be allocated, enough to ensure quite comfortable conditions for inhabitants and enough space for research, mining and other compulsions.
Computations of mining and research areas, as well as large green environments (the mental health of inhabitants is greatly valued) take up most of the available area, and so does food production.
The above mentioned space necessary for each person leads to a radius of 1 km for the inhabited section. The other dimensions have been calculated (required area for food production as found in Human Factors) taking into account the huge amount of food and water consumed.

Area		*Location*
Residential		Inhabitance Module
Office and work		Entertainment Module
Research		Research tube, Agriculture module
Parks		Entertainment Module
Entertainment		Entertainment Module
Mining		Mining Module
		Asteroid Base
		Lunar Base
Industrial zone	power and energy	Mining Module
	glass	
	metal processing	
	the textile	Agriculture Module (cotton, etc.)
	fiber	
	robotics	Research Module
	pharmaceutical	Agriculture Module
	food processing	
	sugar	
	water purification	
Population	Permanent	10.000
	Transiting	2.000
Energy	Solar panels	Inhabitance Module
	Nuclear	Nuclear Module
Elevators		Spokes
Docking system		Exterior Spaceport
Thrusters		Exterior
Spaceport		Exterior Spaceport
Spaceport gates		Exterior Spaceport
Outer space windows		Inhabitance Module
Bases		Calisto Base

	Ganymede grid	
	Lunar base Module A	
	Lunar base Module B	
	Asteroid Base 1	
	Asteroid Base 2	
	Asteroid Base 3	
	Jupiter mining site	
	Asteroid belt mining site (1)	
	Exploration modules	Telescopes (no.: 25)
		Miner (no.: 10)
		Mass catcher (no.: 5)
	Odysseus Amun Mining Module (no.: 1)	

Zone	*Area allocated per person* ($\boldsymbol{m^2}$)
residential	100
office and work	25
research	50
parks	75
entertainment	50

The production areas needed for the necessary life support elements, as well as research, mining and rocketry, are not considered here, but plenty of areas are foreseen, food and water production being sufficient. This is described in the Human Factors section.

a. Gravity and Pressure (Rotating and non-rotating modules)

Gravity, in terms of a gravitational acceleration of the same magnitude as on Earth, is crucial in space settlements. People are not accustomed to microgravity, which takes severe impacts on muscles, bones and muscle structure (as described in Medicals). Gravity is ensured through magnetic rotation and poles changing. The central magnetic structure represents a huge, very strong electromagnet, meant to hold the settlement and rotate it.

Rotation is done by changing the poles, the main structure rotation tube being attracted to the positive and negative polarities successively. The three large structures at the settlements' extremity do not rotate, the triangular spokes holding them being linked to the main structure through magnetic frictionless bearings.

b. Structural resistance

The structural resistance of the settlement is mainly given through the materials used. These are all described in the Material section. Moreover, the structure of Bellevistat is symmetrical and balanced, in order to prevent any potential accidents or instabilities. In the event of an asteroid reaching Bellevistat's proximity (unlikely, given the location), the settlement is endowed with departure rockets while the

triangular spokes can be lifted and launched away from the settlements main body, avoiding collisions with external large celestial bodies, such as asteroids.

MAIN STRUCTURE

The main structure is composed of three central microgravity and operations research zones, surrounded in the magnetic rotation tube, followed by the main body, the inhabited sections, the entertainment zones, and finally the mining sites, nuclear and energy modules.

Module	*No*	*Location*	*Radius*	*Height*	*Width* m	*Circumference* $a°$	*Area* m^2	*Volume* m^3
Inhabitation	6	1g	1km	150m	500	30°=>521.67m	78250.5	39,125,250
Entertainment	6	1g, linking inhabitation	1km	150m	500	90° =>1565m	234750	117,375,000
Agriculture 1	6	On the triangular spokes(0g)	1.5km	300m	600	45° =>1173.75m	352 125	211,275,000
Agriculture 2 (3 distinct floors)	18	0.5g	800m	200m	400	30°=>417.33m	83466	333,864
Agriculture 3 (2 distinct floors)	12	0.5g	800m	200m	400	30°=>417.33m	83466	333,864
Storage	6	6 of the two floor agriculture zones	800m	200m	400	30°=>417.33m	83466	333,864
Research 1	3		600m	100m (thickness of tube)	150	360°=>3756m	375600	56,340,000
Research 2	1	1 of the two floors agriculture zones	800m	200m	400	30°=>834.66m	751 200	300,480,000
Energy	1	One of the extreme structures	2km	350m	550	60°=>2086.7m	730 100	401,555,000
Mining 1	1	One of the extreme structures	2km	350m	550	60°=>2086.7m	730 100	401,555,000
Mining 2	1	One of the extreme structures	2km	350m	550	60°=>2086.7m	730 100	401,555,000
Linking 1	6	Between	1km	-	200	10°=>173.9m	34780	-

		inhabited sections						
Linking 2	6	Triangular linking	2km	-	1000	-	-	-

The radius represents the distance of the module from the center. Circumference = $\frac{2\pi r a°}{360°}$

SHAPE DESIGN

Tubes	
Advantages	*Disadvantages*
Constant gravitational acceleration	Small width
More space efficient than a torus	Height and width inversed
Doesn't require a large air volume	-
Can easily be illuminated	-
Easy to expand by adding similar structures	-

Cylinders for Transport	
Advantages	*Disadvantages*
Safe, ideal for pipes, fibers and elevators	If large, psychological effects may occur
Do not require huge amounts of material	-
Stable, easy to build, fix and expand.	-

Tube sections	
Advantages	*Disadvantages*
Give the exact volume needed	Slight gravitational variation
Gravity may vary by very small amounts, as opposed to other structures	-
Optimizes air production and circulation	-
Optimizes space available	-
Ideal from a financing and materials used point of view	-

a. INHABITANCE

There are three inhabited zones in each human development section, making six total inhabitation areas. These are solely designed with the purpose of accommodation, housing, medical and schools. All other living compulsions such as entertainment, reside in the environmental zone.

Floor	*Subfloor*	*Height*	*Width*	*Circum.*	*Area*
Inhabitation 150 m	Inhabitation 1	30m	400m	521.67m	78250.5 m^2
	Inhabitation 2	30m	400m	521.67m	78250.5 m^2
	Inhabitation 3	30m	400m	521.67m	78250.5 m^2
	Schools and Medical	30m	400m	521.67m	78250.5 m^2

b. ENTERTAINMENT, HEALTH AND PARKS

Although the shapes are slightly different, with a smaller gravity in the entertainment zone, we believe that it is salubrious for inhabitants, especially as the gravity varies only slightly. The entertainment module holds shops, commercial area, café's, cinemas and a museum, to remind people as much as possible of home. The settlement university also resides, in buildings, at the far extremities of the module, where gravity resembles the gravity in the inhabitance module most.

Floor	*Subfloor*	*Height*	*Width*	*Circumference*	*Area*
Entertainment 150m	Shops and commercial area	30m	400m	1565m	234750 m^2
	Parks	60m	400m	1565m	234750 m^2
	Café's, Supermarkets	30m	400m	1565m	234750 m^2

The entertainment area does not reveal itself as an actual street infrastructure, resembling a central large pedestrian area with shops, supermarkets and café's, as well as cinemas on the sides.
Parks cover a large sector of the entertainment zone. Although the settlement has been initially thought of as modern and very space efficient, the inhabitants' mental and physical well-being are very important. The park floor is 60 m high and presents an attempt of designing real terrestrial nature. It will have a stream, gravitationally accelerated through the floor, as well as tall trees, flowers and animals.
The entrance and exit systems are designed just like the ones in modern zoos. Flora and fauna will only be represented by small animals while plants range in all sizes, preferably resistant, adaptable ones. These elements are all descried in the Human Factors sections.

c. AGRICULTURE

Module	*Subfloors*	*Description*	*Height*	*Width*	*Circum.*	*Volume*
Agriculture 1 Numbers: 6	aeroponic	Food production	150m	600m	352 125 m^2	211 275 000 m^3
	hydroponic		150m	600m	352 125 m^2	211 275 000 m^3

Agriculture 2 (3 distinct floors) Numbers:18	aeroponic	Food production	100m	400m	83466 m^2	333 864 m^3
	hydroponic		100m	400m	83466 m^2	333 864 m^3
Agriculture 3 Numbers:12 (2 distinct floors)	aeroponic	Food production	50m	400m	83466 m^2	333 864 m^3
	hydroponic		50m	400m	83466 m^2	333 864 m^3
	Meat production		100m	400m	83466 m^2	333 864 m^3

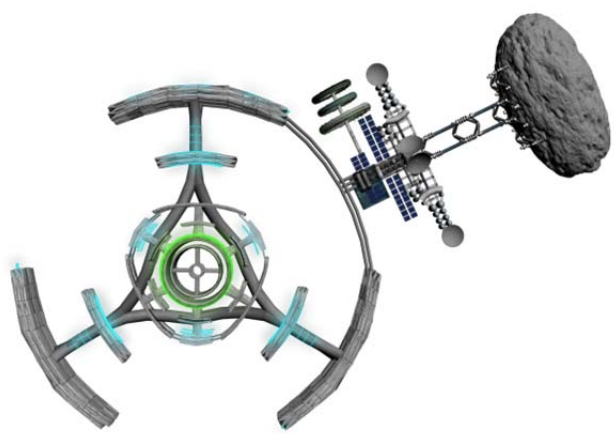
The circumference and area stay the same as computed above, since the large module is split into equal floors. The only parameter which suffers modification is the volume, which must be divided by the number of floors.

d. AEROPONIC AND HYDROPONIC

Agriculture and food production is done through hydroponic and aeroponic techniques, as described in the Human factors section. An adjacent level is added to the Agriculture 3 module for in-vitro meat production.

e. NUCLEAR

Most of the energy used on Bellevistat is generated through nuclear fission. Thorium reactors are placed at the extremities of the settlement, as depicted. After energy is generated (by turbines) and converted to electrical energy, they are transported through the spokes all around the settlement, and converted into DC. Since electrical current does not have to be transported on large distances, AC will not be used (given the extremely high voltages), and all current is DC transported. Loses due to wire resistance are found in Appendix A.



f. MINING ON BELLEVISTAT

Mining is a very important section on Bellevistat and represents one of its main purposes. Besides the obvious aspects of lunar and exterior asteroid mining, external, rather small, below 500m wide asteroids

are captured, docked and mined on Bellevistat. The main purpose of asteroid docking is not mining however, but research for permanent bases inside asteroids. Conclusively, the interior bulk of the asteroid is mined and processed, used for resources, financing, building materials, as well as hardening the structural resistance of the future interior asteroid base.

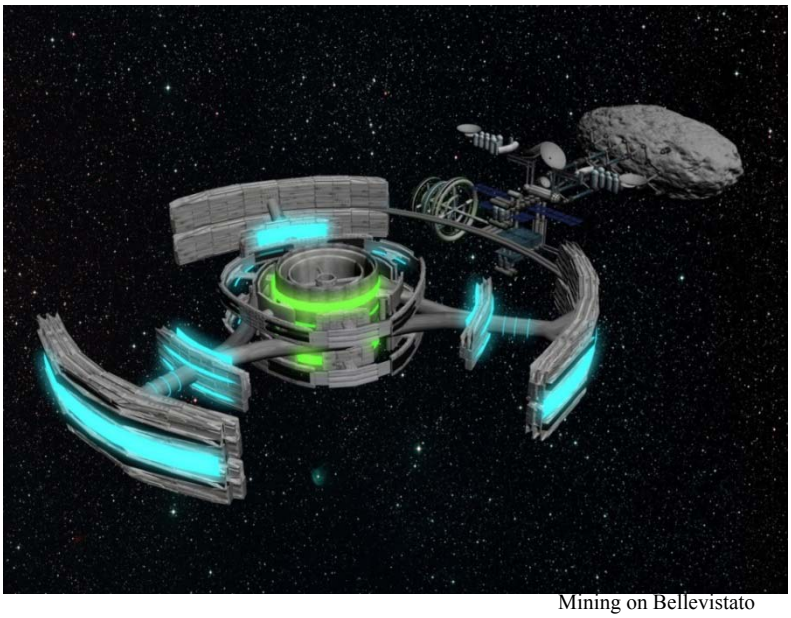
An interior asteroid base is very feasible, since it provides natural radiation shielding (one of the main problems in aerospace) plenty of space and, if asteroids large enough come across and present potential future inhabitation zones, actual natural gravity and soil for gardening (regolith may be enriched and used as soil).
Moreover, the magnetic field generated by Bellevistat will be made as so to equivalate the gravitational attraction between the settlement and the asteroid.
The mining module is linked to two of the three extreme modules of the settlement. Although most of the processing is done in the two tubular sections, centrifugal volatile separation is taken care of on the three rotating tori on the base itself. The 0g environment on the tubular sections is ideal of mining and processing, and the proximity to the settlement ensures we can send manned missions.

g. INDUSTRIAL

Most of the industrial activity takes place outside the main settlement, but some elements of mining are present, as described above. Rocketry and robotics are research topics, hard-core rocketry being done on the docking platforms, attaching any modules magnetically.

h. RESEARCH

The main research sections reside inside the magnetically shielded tube, at the very centre of the settlement. Three tubular modules, all linked through spokes are presented there. They are 250m wide, and make up one of space research's most important condition: microgravity. Research is fully described in the research chapter and is done both on the settlement, as well as in exterior missions.


Mining on Bellevistato

i. STORAGE

Storage is also very important element of space life. Any extra materials, food or water resources should be safely stored and available for future usage. The storage areas are placed in lower gravitational acceleration areas, in such a way that materials that require storage (food from even lower gravitational areas) can be *moved without any usage of energy, through the aid of gravitational acceleration.* More than that, if any need of stored materials appears, these are once again moved with no energy consumption from one zone to another.

This is highly advantageous since one of the *most important areas taken into account when designing Bellevistat was efficiency and ease of transportation.*

j. LINKAGE

Linking the modules together and optimum communication of Bellevistat modules is a key factor in the space settlement design. Spokes link all elements together and goods docking systems are present all through the design. Spoke elevators link the two inhabited modules and thin paths through the structure spokes link research and mining to the rest of the settlement. Magnetic, Eddy currents elevators transport people from one side of the settlement to the other.

The pictures on the following pages represent schematics of the settlement, showing what modules represent what sections of the settlement (egg. inhabitance, entertainment, nuclear, etc.).

RADIAL COORDINATES

Module	*No*	*Radial Coordinates*
Inhabitation	6	(2,285)-(2,315)
		(2,165)-(2,195)
		(2,35)-(2,75)
Entertainment	6	(2,195)-(2,285)
		(2,330)-(2,45)
		(2,75)-(2,165)
Agriculture 1	6	(2,345)-(2,15)
		(2,105)-(2,135)
		(2, 225)-(2,255)
Agriculture 2 (3 distinct floors)	18	(1,45)-(1,75)
		(1,165)-(1,195)
		(1,285)-(1, 315)
Agriculture 3 (2 distinct floors)	12	(1,105)-(1,135)
		(1, 225)-(1,255)
		(1,285)-(1,315)
Deposit	6	(1,45)-(1,75)
		(1,165)-(1,195)
		(1, 285)-(1,315)
Research 1	3	(1,0)-(1,360)
Research 2	1	(1, 45)-(1,75)
Energy	1	(3, 90)-(3,150)
Mining 1	1	(3,210)-(3,270)
Mining 2	1	(3,330)-(3,30)

SOLAR PANELS

Advantages	*Disadvantages*
Noiseless	High initial costs
Present no mobile sections	Generate DC
No emissions	UV at 5 A.U. in very small quantities
No need for water/fuel	Used only to intercept "wasted" Sun
Minimal maintenance requirements	-
Long lifetime	-
May be modularly designed	-

a. GALLIUM ARSENIDE

Solar panels use photovoltaic cells (where more cells create a panel) in order to turn sunlight into energy. Since many semiconductors create a triple-junction cell, each chosen to absorb a certain area of the solar color spectrum, three different type of conductors are needed in order to make the conversion efficient. A 65% conversion rate is assumed, given the 28.8% obtained today outside laboratories.

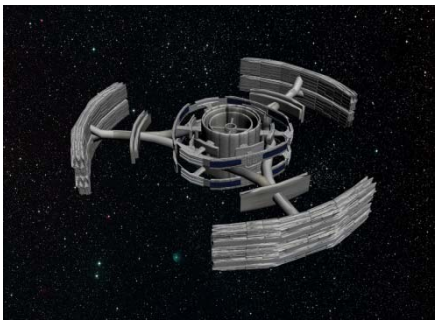
b. USAGE ON BELLEVISTAT

Location

Solar panels are of low occurrence on Bellevistat, since the settlement is located at 5 AU from the Sun and the radiation received is very small. They are however located inside the inhabitance module, to receive lost emitted UV light. Besides, Gallium Arsenide panels receive energy in all spectrums, so even the emergency and signal light are received and converted to energy, making Bellevistat highly efficient. Solar panels are placed inside the inhabitance module, in order to absorb some of the light emitted when natural light is simulated.

Only photons of appropriate energy can be absorbed and generate electricity using the semiconductor material. Therefore, it is important to know the spectral distribution of any solar cell used, to solar radiation. The two most used parameters describing solar cells are spectral power density, the incident power of solar radiation per unit are per unit wavelength, and the photon flux density, the number of photons per unit area per unit time per unit wavelength.

Construction Sequence



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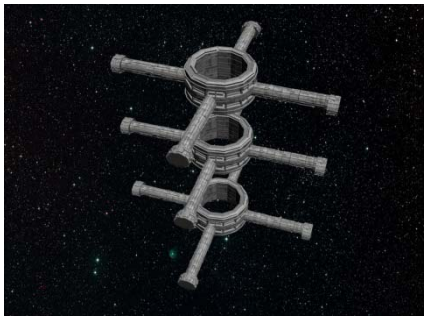

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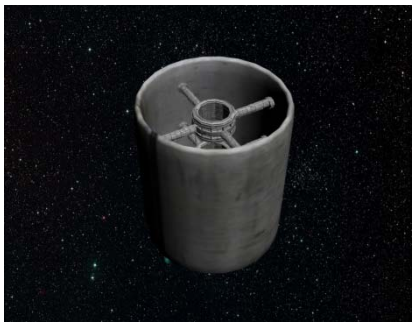

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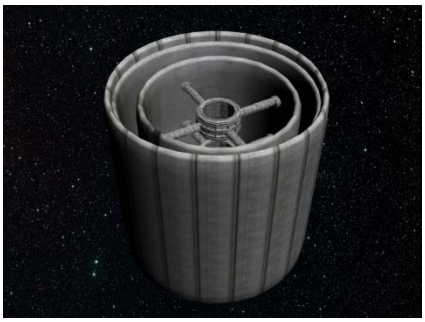

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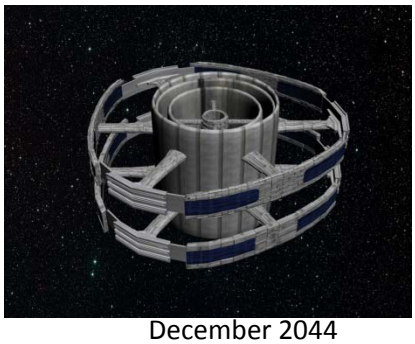

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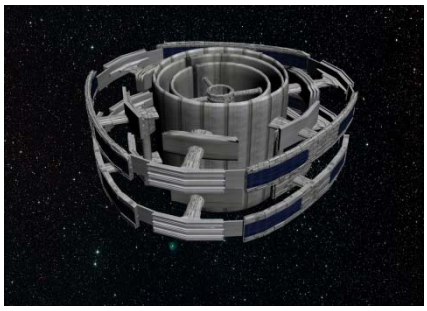

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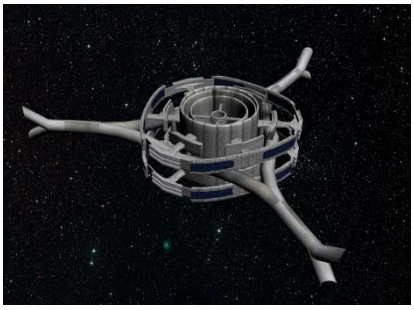


December 2048

ARTIFICIAL GRAVITY

The effects of microgravity on health, as well as all the reasons for artificially generating gravity are presented in the Human Factors section.

GENERATION OF ARTIFICIAL GRAVITY

Artificial gravity is a vital component of life and must be greatly considered in the space settlement design. There are many available ways of generating artificial gravity, from using a body with a large mass to linear, "Star Wars" acceleration.

Artificial gravity by using a celestial body is not recommended, as something with a very small radius, yet very dense would be required. Moreover, it should generate exactly g = 9.8, since dramatically increasing the radius of the settlement is not feasible or affordable.

Linear acceleration is generated by motion. Conclusively, the space settlement would have to move at great, yet constant speeds without stopping. This will generate gravity on half the settlement rendering this method as inefficient and very expensive, fuel-wise.

Finally, the most efficient method of gravity generation is through angular rotation of Bellevistat, around its own axis. This will exert gravity on the inner sides of the tubes, thus giving the opportunity of multiple levels of accommodation.

GRAVITATIONAL ACCELERATION-MAGNITUDE OF ANGULAR VELOCITY

$$F_{cf}=\frac{mv^2}{r} \text{ (1) and } G=m\times g \text{ (2),}$$

But since F=G and (1), (2) we obtain: $g=\frac{v^2}{r}$.

But $\frac{r}{t}$ =v=ωr, and therefore $g=\omega^2 r$.

Finally, the angular velocity ω is equal to $\sqrt{\frac{g}{r}}$, where g equals 9.80665 N/kg.

Section	*Radius*	*Angular velocity*	*Corriolis acceleration*
Inhabited	1km	0.098 rad/s	0.3332 rpm
Agriculture 1	1km	0.098 rad/s	0.3332 rpm
Agriculture 2	1.5km	0.081 rad/s	0.2754 rpm
Entertainment	800m	0.110 rad/s	0.374 rpm

The agriculture modules are situated in a lower gravitational influence than the inhabited modules. Studies have shown that plants have been known to grow faster in a lower gravity medium. Similar information has also been shared in the past years at ISDC - International Space Development Conference.

From $T = 2\pi/\omega$ and $v = \omega r$ results that the Corriolis acceleration, $ac = 2\omega v$, which due to psychological concerns must be under 2 rpm (individuals adapt, however, to accelerations between 2 - 7 rpm).

The rationale for the maintenance of low Corriolis acceleration is the mental and physical health of Bellevistat inhabitants, as the Corriolis effect may induce symptoms as nausea, dizziness or anything similar to sea or motion sickness. The Corriolis acceleration is found for a person walking with an average 1.7 m/s.

Radius	*Gravity*
Minimum: 800m	0.110 m/s^2
Medium: 850m	0.106 m/s^2
Maximum: 950m	0.321 m/s^2

Since Bellevistat is a very adjustable space station, the non-rotating modules, as well as the interior research modules, magnetically rotating, can be controlled to provide gravities of 0.5g, 0.8g and 1g. Pressurized modules can be alternatively pressurized, the pressure being raised by adding air quantities to the same module, or by letting air go through valves, in order to attain variable pressure of 0.6, 0.8 or 1. (as well as anything in between).

DOCKING

Bellevistat is going to be an incredibly busy hub of activity. What with cargo shipments from the Earth, transports coming to drop off passengers, ships stopping to refuel before departing for other solar system destinations, and the many other ways in which Bellevistat is going to serve humans, it is inevitable that a great number of spacecraft will be constantly visiting and leaving the station every day. Therefore, it is imperative that an efficient system is put in place that allows ships to easily dock with Bellevistat. This system must be flexible in that it can support a wide variety of ships of all sizes and spatial configurations so that no visitor is turned away due to a technical problem.

To solve this dilemma, a station-wide system of extendable electromagnetic booms will be installed around the docking tubes, the thinner intermediary segments of the outer perimeter of the station. The aforementioned booms will essentially be reinforced steel rods extending radially outwards from the docking tubes.

At the end of the boom, there will be a strong electromagnet through which current can be passed to control the strength of the resultant magnetic field. This allows two docking possibilities on the part of the ship: if the ship has a hull made from a magnetic material, then the electromagnets can latch directly onto the ship's exterior once the ship is close enough and in an appropriate position. The other possibility is that the ship may have special exterior docking ports with their own electromagnets to which the booms' electromagnets can directly couple. As there is currently no international standard for docking, it would be wise to assume the defensive position that there will be no universal docking standard in the future either. Therefore, while it would be preferable for the other ships to have this electromagnetic docking port, it is advantageous that the option at least exists for ships that have some exterior magnetic component to be docked with Bellevistat as well. A positive aspect of the electromagnetic docking port is that it ought to be fairly simple to install along the exterior of any ship, so that any ship lacking a magnetic hull that still wished to dock with Bellevistat ought to be able to do so after a fairly minor repair. The hope of the designers of Bellevistat is that the electromagnetic docking method is able to catch on sufficiently within the aerospace community such that it can become a widely implemented system for all ships and stations, if not an industry standard.

The booms will not be single cylinders; rather, they will be a telescoping series of three concentric cylinders with small servomotors in-between. These will allow the booms to have variable lengths, extending and contracting as needed. In this way, the docking system will be capable of accommodating ships with any size or spatial configuration. The ship need not have a perfectly straight side to which the booms can mate; rather, the booms will conform to the shape of the ship and ensure that a snug connection is made. The booms will be placed apart with an inter-boom distance of five meters, so large ships can occupy as many booms as are required to dock with Bellevistat. The booms will have a minimum length of one meter and a maximum length of ten meters, although the designers anticipate that such extremes of length will rarely be required.

The entire docking process will be automated so that it can operate at maximum efficiency. As a ship approaches the station, Bellevistat's radar network will detect it and will broadcast an automated "welcome" message when the ship is approximately two kilometers away. The message will request the purpose of the ship's voyage as well as the number of passengers onboard. The ship's response will be analyzed by a computer which will designate the ship to one of the three docking tubes. It will communicate directly with the ship's onboard computer to have it position itself next to the appropriate electromagnetic booms. Bellevistat's docking computer will use a space-filling algorithm to ensure that the ship is added to the fleet of already docked vehicles in such a way as to use the minimum number of booms while leaving spaces large enough to accommodate for any other possible ship configurations.

When the ship approaches its docking position, the booms will begin to reconfigure themselves in response. On either side of each boom will be a stereo time-of-flight infrared range

imaging system. Infrared lasers will be swept out radially along the surface of the ship, producing live three-dimensional scans that accurately gauge the distance between the station and the various parts of the ship's external geometry to an accuracy of one millimeter. The booms can then extend outwards to connect to the ship, either to its hull or to its magnetic docking ports. The booms will then retract to minimize the distance between the station and the ship.

There will be a total of three docking tubes, each performing a different task. There will be one for passenger transports, one for repairs, and one for cargo shipments. The system of booms will be the same for each docking tube; the only difference will be in the peripheral machinery specified by the task at hand. Specifically, the booms of each type of docking tube will have different types of robots present. For cargo docking tubes, large industrial robots with powerful propulsion drives and magnetic clamps will enter the cargo bay of large ships and transport shipping containers to appropriate areas of Bellevistat. For repair docking tubes, teams of small robots equipped with a suite of advanced tools will swarm around the ship, producing three-dimensional scans of the exterior, determining the repairs that must be performed, and implementing said repairs. For the passenger docking tubes, a small transport robots will be used to ferry groups of passengers from the ship to airlocks located on the inside of the docking tube. In this way, all the passengers can be quickly brought onto the station and acclimated to their new surroundings.

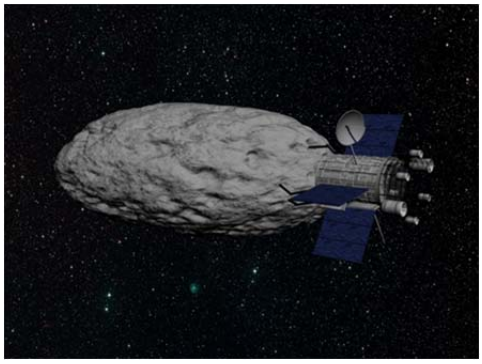
3. OPERATIONS AND INFRASTRUCTURE

1. Feasibility

There have been a huge number of proposals and companies starting up in aerospace industry and asteroid mining and this is just the beginning. Space travel has long been considered, and this year, yet another group of enthusiasts started what is now called: *the second space race.*
Should one of the aerospace-oriented star-up companies succeed, others involved will join by either investing or developing projects of their own.
SpaceX already took over rocketry, Virgin Galactic is a pioneer of commercial space travel, and Planetary Resources Inc. in the first company to completely focus on asteroid mining. This has been a trend in the past decade, reducing aerospace exploration and mission costs with SpaceX also dramatically reducing the cost for providing supplies on the ISS.

2. Finding and Choosing Asteroids

An asteroid of 25 meters diameter is the equivalent of 1.5 million tons of construction material. A number of about 200,000 NEAs (Near Earth Asteroids) 100 meters in diameter and larger, circle or meet Earth's orbit in one point.
Asteroids have two main features we have to consider: they are extremely *rich in metal* - a planetoid contains 30 times the amount of metal ever mined from Earth and they have a *rocky-ice like texture*.



GEO telescopes

As described in Financing, before asteroids are chosen or mined, they are first followed up, and selected from a large palette. In order to ensure that, complex networks of telescopes are first launched.

Launcher

The telescopes in GEO will be launched with SpaceX's light-weight launcher Falcon 1e, capable of lifting up to 1,010 kg to LEO, the payload consisting of the telescopes themselves, endowed with transmitters, mining devices, dating and sampling components, infrared vision, cameras, sensors, gyroscopes, star sensors for attitude control and others similar, each weighing a few kilograms.
It is powered up by its single Merlin 1c and uses liquid oxygen as a propellant. The second stage Kestrel engine burns up to 3,000 kg of propellant. The launcher is restart able and able to burn for up 418 s.

3. Asteroid composition

Currently, there are no clear records or patterns in asteroid composition. Most asteroids contain iron-nickel, cobalt, platinum and a rocky-icy crust. Their composition, however, may consistently differ.

Type	*Description*	*Usage*
Lithophile	earth-loving and consists of silicate rocks, calcium, magnesium, as well as other minerals	M-type and C-type ones: various metals, iron, nickel as well as minerals and carbon. Represent 10% of total asteroidal mass.
Siderophile	iron - loving	
Chalcophile	made of sulfur	
Volatile	lost in liquid stage, but containing useful elements for rocket fuel	space-made rocket fuel

Composition	*Percentage of asteroids*
Carbon	75% or more
Silicate	Less than 17%
Metallic	Less than 7%
Dark (basaltic)	Less than 1%

4. Asteroid location

Pre-requisites:

- The asteroid must be accessible
- The asteroid must have a low orbital eccentricity (considering e = 0 when the orbit is circular), with a long, productive mining season
- Low delta-V when reaching the transfer orbit, a delta V lower than 6 km/s, and a return delta-V lower than 2 km/s (energy consumption is lowered).

5. Mining

Mining in a low-g environment may raise a few difficulties. Conclusively, asteroids that rotate must be either stopped (if the angular velocity vector is too large) or mined taking advantage of the rotating motion. Magnetic landing is the best option in the case of magnetic (M-type) asteroids, composed primarily of metal, revealing ferromagnetism. Attachment will be done using magnetic terminations of the robot, since claw-structures will be highly inefficient against metal.

Considering the small dimensions of an asteroid, landing is not a problem and may be considered semi-permanent attachment, springs or thrusters leading the mining module off when the mission is completed. The process of separating rock and dust from metal will be completed as described below. Asteroids are rich in nickel - iron metal granules. In order to separate the precious alloy from dirt and complementary asteroid components the mining equipment will use magnetic separation, and is thoroughly described in the Processing subsection of Mining.

The metal will be mined by using a strong magnet and some grinders to separate rock from metal granules, since most of the precious, needed material is located at the asteroid's core.

The process will be unfurled in space. In order to prevent surroundings being polluted with dirt, a huge canvas will create a tent - like bag in which the rocky remains would be stored. The rotation speed will constantly slow down by throwing the nickel – iron - cobalt alloy in a direction opposing the rotation of the asteroid.

THE CANOPY METHOD

Strip mining involves dusting up the asteroid with precious metal ores being thrown up in the perimeter of the canvas. Small thrusters at the canvas hold-up proceed to rotate the small asteroid, also centrifugally sending the ores to the module (centrifugal push of the force).

This would be both efficient in terms of loosed ores and environmentally protective, especially for Near Earth Asteroids. If the canopy mining proves to be inefficient, then tunneling through the asteroid with robotic arms attached at the far end would be a good alternative.

6. PROCESSING

Processing is done differently depending on the material, being far better to complete this step in space rather than on Earth, as the absence of gravity indulges work with large, massive structures, as well as with high temperatures.

1) Magnetic separation

Mining is done with the use of magnets and so is the metal processing. The obtained metal is run through a grinder, then a roller and finally released at full speed towards a magnet, which may also help flatten it into a bag. The drums and magnets used will be electromagnets, able to generate a magnetic field because of electrical current.[1]

(picture: http://www.permanent.com/space-industry-magnetic-beneficiation.html). (According to Bellevistat and P.E.R.M.A.N.E.N.T.)

[1] http://www.aamag.com/hvydrm.htm

2) Silicates, Volatiles and Minerals

Silicates are turned into glasses, ceramics, or fiber glasses after being passed through a thermal oven. They are also used to create astercrete, a compound resembling dirt, for plant growth on a potential base.
Volatiles are cooked out in solar ovens. After being melted down, again by solar ovens, electrodes are put in and high voltage is passed through the composition. The metals go the negative end, the cathode, while the minerals go to the positive end, the anode. As melting requires high-energy amount, this process will be done only if found enough feasible.

7. Material separation

Minerals electrolysis

To achieve minerals electrolysis, minerals must be first melted, electrodes thrown in, and a strong tension applied. Metals will proceed to the negative electrode (cathode) and oxygen to the anode. This leads to the creation of metal oxides, as long as electrode voltages, currents and temperatures are firmly analyzed and decided upon according to metal specifications.

Considering the effects of vacuum on vapor pressure of metals at various temperatures, metals will be liberated at the cathode in solid form, liquid and vaporous form. For example, aluminum, calcium, sodium or potassium would be in vaporous form. Iron and silicon may be liquid or solid depending on temperature, while titanium would deposit on the cathode in solid form. The separation is done through vacuum distillation.

8. Transport of Goods

The launchers that should transfer the mined load from the asteroid to the settlement are designed accordingly to the Falcon family, but not as powerful. Considering the low gravitational attraction exerted by most asteroids (leg-power is sufficient for departure), the only restrictions imposed on rockets are sustainability and capacity of transporting large loads.
As in the Falcon family, the rockets will be multiple - staged, running on liquid oxygen combined, most certainly with atomized aluminum powder (easy to mine from most space zones). The Falcon family rockets also exhibit reusability properties, also found in the Bellevistat – rockets.

9. Lunar Mining

c. Introduction

Given the minimum opposition raised by the gravitational attraction, an electric slingshot, already designed and named ”Mass Driver”, would suffice the launch of materials in a circular orbit around the Moon.

Taking advantage of the Sun, solar ovens should be built on the Moon to process silicates and volatiles. The solar oven processing method is described in asteroid processing, earlier in the chapter. It will be powered by solar arrays. An overview on the Moon's resources would include the mention of silicate dirt, abundant in oxide metals, silicon, and free iron granules. Large metal ores are completely absent and the existing iron granules are due to asteroid impacts. These impacts are also the reason of the Moon's dusty appearance in the first few meters with much denser, hard to mine, geological layers below.

Element	*Lunar Highland*	*Lunar Lowland*	*Issues*	*Applications*
Oxygen	446,000	417,000	-	Fuel propellant, life support
Silicon	210,000	212,000	-	Glasses, ceramics, etc. Solar cells.
Aluminum	133,000	69,700	Highlands rich	Electrical conductor, structures, mirrors
Iron	48,700	132,000	Lowlands rich	Structural steel
Calcium	106,800	78,800	Highlands rich	Ceramics, electrical conductor
Sodium	3,100	2,900	adequate?	Chemical processing
Potassium	800	1,100	adequate	Chemical processing

Source: www.permanent.com

The appurtenance to either a highland or a lowland zone gives the main difference in material type-density. Silicate minerals, silicon, oxygen bonded to metal, all float to the surface, and so did calcium silicates. This formed a so-called anorthositic layer. After continuous asteroid impact, highlands of consecutive such layers formed. In high altitude zones, overlapping layers of materials, originating from craters, made of anorthositic Aluminum material exist, while in lowlands, Aluminum and Calcium is found in small quantities, as opposed to Iron, Magnesium and Titanium.

<u>Aluminum</u>

Advantages	*Disadvantages*
Good electrical conductor	Expands and contracts with temperature more than most metals
Lightweight structural material	-
Aluminum mirrors-good for reflectors	-
Atomized Aluminum powder good fuel when burned	-

with Oxygen (good become primary fuel on the Moon)	
High concentrations in anorthite	-
Fourth most abundant	-
Easily shaped and modeled	-

Calcium

Advantages	*Disadvantages*
Side-product of Aluminum extraction from anorthite	Not strong
Pure calcium metal, excellent electrical conductor	Coating calcium zones is necessary, as calcium is being naturally deposited, and may cover mirrors.
Vacuum, calcium doesn't burn (doesn't come in contact with Oxygen)	-
Easily shaped and modeled, machined etc.	-
Lightweight (half-density of Aluminum)	-

Titanium

Advantages	*Disadvantages*
High-strength	-
Extracted from ilemenite, which may yield (through processing) to hydrogen (rare on the Moon)	-

Iron

Advantages	*Disadvantages*
Extracted from ilemenite, along with titanium	-
Some free iron metal (1%)	-
Standard mining technique, powder metallurgy (advantageous as opposed to Earth, since the metal is already powdered)	-
Easily extracted magnetically, after grinding	-

Having all these different, yet necessary resources, different processing methods will be used.
Aluminum oxygen and silicon will be converted to silicates and processed by heat, chemically or through electric current generation and usage. Highland anorthite, $CaAl_2Si_2O_8$ is smelted, finalizing in deposits of Aluminium, silicates and oxygen.
Oxygen is so abundant because it bonds with everything, therefore raising oxide metals to the surface. Metals that do not bond to Oxygen (like gold) sink. Since in-depth lunar layers are settled down, high-vibrations, small explosions or simulated earthquakes, will help mine precious resources. This however must be used wisely, without damaging the Moon.
Another challenge faced when lunar mining, is the raise of friction, from a 1.5, as much as 60 times. Therefore, materials with low friction indices will be used for the drills directly involved in the mining process. Shielding from the extreme temperatures must also be ensured, protecting the mining module.

Besides the typical Mylar, Dacron and Kapton insulation, a canopy will protect the module (since its dimensions are very big, and multiple such mining modules exist).

1. Air Regulation

Oxygenation

It is vital to ensure enough oxygen levels in the air of the settlement at all times, to provide inhabitants with the same well-being they enjoy on Earth.

Oxygen levels within Bellevistat will be monitored and regulated to stay at 20.95(±0.5) % of the atmospheric gas by volume. All major gas levels, including oxygen, nitrogen, carbon dioxide, methane, hydrogen, and water vapor will be measured in all modules of the settlement using local Major Constituent Analyzers (MCAs), which are systems of multiple detectors to measure levels of major gases in order to make sure that the no gas surpasses or falls short of its necessary levels. These detectors will report gas levels to a software mainframe associated with the air recycling facility and gas transportation ducts to maintain constant, safe gas levels at all times.

Oxygen on Bellevistat will come from two predominant sources. One will be a semi-perpetual electrolysis system, which will cycle through its own independent water supply to generate oxygen gas.

A large reservoir of water will be channeled into a reaction chamber, where the large volume of water will be put through an electric current in order to separate the water molecules into oxygen and hydrogen gas. The oxygen gas will be collected and sent for distribution throughout the interior of the settlement. The system will store the hydrogen gas in one tank, and will receive carbon dioxide gas in the other, which will be collected throughout the atmosphere of the settlement as a means of preventing CO_2 levels from exceeding 0.040% in the air. According to Sabatier's reaction:

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O.$$

Therefore, the carbon dioxide, the product of respiration, and hydrogen gas, the product of electrolysis, will be reacted to produce water and methane. This water can then be transported back into the reservoir for use in electrolysis. The waste methane would then be pyrolized to produce carbon and hydrogen gas, the latter of which can further undergo Sabatier's reaction.

However, reliance on one major source of oxygen is extremely risky and imprudent. Any deficiency in the system can jeopardize the entire population. Therefore, a second source of oxygen will always function in parallel with the other. A large-scale chemical oxygen generating system will provide this additional oxygen source. In this system, an inorganic superoxide, chlorate, or perchlorate will be ignited to produce breathable oxygen gas. Together, the electrolysis-Sabatier and chemical generation systems will provide sufficient levels of oxygen free to be automatically distributed throughout Bellevistat based on the necessary amounts to maintain both the proper, consistent composition of the air and one atmosphere of pressure.

Another way of obtaining oxygen in space that should be mentioned is by importing it from the Moon. The Moon dust has a high percentage of oxygen. The process of obtaining any kind of materials from other sources than Earth, as the Moon or asteroids is thoroughly explained in the Materials episode.

Temperature and Pressure

The air in the settlement will resemble that of Earth in order to cater to the health and comfort of the inhabitants. All inhabited areas of Bellevistat, residential and public access will be maintained at a constant pressure of 101.3kPa, or one atmosphere. This pressure, that of the atmosphere on Earth at sea level, will best accommodate inhabitants by allowing for ease of breathing and prevent long-term physiological changes due to respiratory adaptation. In order to maintain this pressure, the mass of gas in each module of the settlement will have to be regulated based on its volume.

Using the ideal gas equation PV=νRT (1), where P equals pressure, V volume, T temperature, R is the universal constant of the ideal gas and is equal with 8314,472 m^3 Pa K^{-1} $kmol^{-1}$, and ν is the mol number.

We also know: $\nu=\frac{m}{\mu}=\frac{N}{N_A}$ (2), m being the mass, N the number of mol, N_A Avogadro's number and μ the molar mass.

Considering (1), $\nu=\frac{PV}{RT}$, and considering (2) $\frac{RT}{PV}=\frac{m}{\mu}=\frac{N}{N_A}$

We have R=8.3142 J/(k*mol), P=101.325 kPa, T=25°C = 298.15K, N_A=6.022*10^{23}/mol and μ=28.98 g/mol.

Composition

The equation for amount of air in need can be written as: $m = \frac{\mu PV}{RT}$

Therefore, by knowing the volume of the enclosure, the molar mass of the gases constituting the air, and by measuring the current temperature, autonomous onboard and localized MCA systems will be able to report the amount of gas needed to maintain one atmosphere of pressure. The necessary masses of gas for each public-accessible area of the settlement, calculated using the derived equation above, are as follow.

Along with oxygen, the levels of other gases must also be regulated in the atmosphere. High levels of carbon dioxide, for instance, can lead to difficulty breathing and long-term respiratory complications along with other, more dangerous and acute effects. Thus, the gas should not exceed levels of 0.040% in the atmosphere. When MCA units in any of the locations detect high or climbing levels of carbon dioxide, they will trigger local Carbon Dioxide Removal Assembly units, which will isolate and capture some carbon dioxide from the air, thus reducing its levels. The CDRA system will consist of a network of sieves known as zeolites, which are silicon dioxide and aluminum dioxide crystals. Each crystal can be used as a screening system by being flattened out as a porous sheet with holes only large enough for specific molecules. The sieve itself will consist of 4 beds, each with 2 zeolites. The first zeolite, zeolite 13X, will absorb water molecules from the incoming air, passing on dry air to the second zeolite. The zeolite 5X bed then removes the CO_2 from the air, releasing the carbon dioxide-free air back into the atmosphere. The CO_2 removed by this process would then be contained and transported to the air management central facility to undergo Sabatier's reaction in order to produce the H_2O needed power electrolysis.

Other chemical impurities include ammonia, acetone, and carbon monoxide. They can be removed from the air using charcoal filtration. Small active filters will be placed throughout the settlement to trap impurities and keep the air clean and healthy.

2. Water

PRODUCTION

Way of obtaining water	*Phase*
Chemical reaction	Construction
Moon	Construction
Byproduct of fuel cells	Final
Sabatier Reaction	Final

The settlement will need to provide its own water, which could be collected, sterilized, and reused. It is vital that all water is effectively contained within the settlement, where it can perpetually cycle, without being lost to the surrounding space.

All initial water will need to be transported to the settlement from Earth. This would provide all of the water the settlement will ever need when population projections are factored in over a long scale of time as the population of the settlement approaches its maximum capacity. Enough water will need to be initially supplied to, moreover, meet such demands. The first way is by using oxygen and hydrogen and creating chemical reactions in order to obtain water. Both oxygen and hydrogen are abundant on the Moon, and hydrogen is the most common substance in space. Since the research torus is the first to be constructed, oxygen may be produced in an early stage of construction.

$2H_2 + O_2 = 2H_2O$ + E

The second way of obtaining water in space during the construction phase would be taking it from the Moon. LCROSS found a shadowed area near the Moon's South Pole, in the Cabeus Crater.

COLLECTION

The water within the settlement will be recycled and purified for use and reuse. Water will come from three predominant sources. The first is any water obtained from the waste of water sources such as residential sinks, commercial sinks, fountains, and bodies of water. This water will be collected in a system of ducts that will transport the water to localized reservoirs to be temporarily held in order to regulate water flow levels and prevent an overflow in the central water channeling system. From these storage regions, the water will proceed to a larger main reservoir located within each module before entering the purification process. It is important to have multiple reservoirs and purification centers on the settlement to prevent dependence on any single region in the case of an emergency failure or improbable contamination issue.

The second source of water for sterilization would be urine, without which it would be impossible to maintain water levels within the settlement. This waste would be filtered through the septic system via centrifugal separation, isolated, and stored in localized reservoir containers

TREATMENT

In the regional water recycling centers, water will arrive separated into the three reservoirs of wastewater, urine, and atmospheric water vapor. Since water vapor levels will be relatively low in comparison to the other two sources, the collected water vapor will ultimately be combined with the wastewater before undergoing filtration.

The settlement will take advantage of forward osmosis as its primary means of filtration. In this process, water is placed in a chamber separated down the middle by a semi permeable membrane similar to the

apparatus of reverse osmosis. However, this process takes advantage of water's natural osmotic properties by placing a high-concentration solution of ammonia salt on the opposite side of the membrane. From here, the filtered water will be channeled into a final chamber for ultraviolet sterilization to kill any pathogens that may have passed the forward osmotic membrane. In this process, the water will be passed through a chamber in which ultraviolet rays will be passed through without causing any toxicity to the water itself. A UV dosage of 7,000 $\mu W \cdot s/cm^2$ is sufficient to kill most harmful pathogens

Distribution

From here, water will enter a new product water reservoir from which it will be channeled as necessary. The product reservoir will transport water through ducts into various local reservoirs throughout the module. The water will then be brought up directly through plumbing for use. A large amount of the water will be used residentially, with applications such as dishwashing, kitchen sinks, showers, and toilets. Additionally, water will be used to maintain current bodies of water, such as scattered ponds, as well as streams that can be found in local parks. In other modules, water may be used for research purposes or for food production and processing.

3. Food

Dietary Requirements

Maintaining a proper diet is integral to the health and wellbeing of every inhabitant of the settlement. In order to sustain a healthy population, food intake must be moderately regulated to best meet an individual's dietary needs. The specific requirements will vary from person to person depending on age, weight, sex, daily fitness, and any ongoing or acute medical conditions. However, an approximation of the ideal caloric intake with respect to the major food groups is as follows below:

Group	*% of Daily Caloric Intake*
Carbohydrates	40-60%
Proteins	20-40%
Fats	20-30%

Although it has been established that each individual will have a specific dietary requirement, the measured nutritional needs of an average human being in order to maintain and develop on good health will here be used to represent the needs of the general population of inhabitants. The following table lists the necessary food groups, the quantity with which they will be consumed daily, and the nutrients they will provide.

Group	*Nutrient components*	*Amount/day*
Grains	Protein, Vitamins B_1 and B_2, Iron, and Fiber	170-200g
Dairy	Protein, Fat, Vitamin B_2, Calcium	3 cups
Meat, Eggs, and Poultry	Protein, Fat, Vitamins B_1, B_2 and D, Calcium, Iron	150g
Fruits	Vitamin B_2, Folic acid, Carotenoids, Iron, Fiber, Potassium, Sugars, Vitamin C	2 cups

Vegetables	Vitamin B_2, Folic acid, Carotenoids, Iron, Fiber, Sugars	3 cups
Fat and Sugar-Rich Foods	Sugars, fatty acids	Minimal amounts

As previously states, the dietary requirements are dynamic parameters that are specific to the body type, age, gender, size, and physical condition of the individual. Therefore, the food provided to each individual will be specialized based on bimonthly physicals in which manual and blood tests will measure blood glucose, protein, fat, and nutrient levels in the body. These bimonthly reports will be entered into a settlement-wide healthcare computer system, which will algorithmically determine the proper dietary needs of the individual.

In order to ensure that each resident consumes sufficient levels of vitamins, minerals, and essential amino acids, food produced in the settlement will be supplemented with spirulina. Spirulina is a cyanobacterium that is approximately 51-71% protein. It includes every essential amino acid, as well as a large variety of vitamins and minerals. It will be grown in a hydroponic growth medium.

PRODUCTION

The food consumed in the settlement will be made through various methods that are efficient and have high production yields. All plant-based food products, including fruits, vegetables, leafy greens, and sugars, will be grown in large aeroponic and hydroponic systems in each main module of the settlement that allow for efficient microgravity agriculture**.**

Aeroponic systems allow for plant growth sans growth medium. This is done by exposing roots directly to water through a mist environment. The solution that meets the roots also contains all necessary nutrients for plant growth. Employment of such aeroponic techniques allows for a highly efficient delivery of oxygen and carbon dioxide to the plant roots, aiding development.

Aeroponic methods will be used in the agricultural areas of the settlement to grow vegetables and greens. Other products will be produced using hydroponics, a term for a system that grows plants in a mineral solution without the need for a soil medium. This system too is beneficial, since the water needed can be recycled throughout the system without need for significant further input, greater control of nutrient levels the plants receive, and, as is the case with aeroponics, easy harvesting, and disease prevention.

Hydroponic systems will have Plasma Growth Lights, which have the widest spectrum and give the most light, and Digital Ballasts, which give more light but loose less electricity when heated.

Fertilizers are hydroponic and organic, and propagation will be ensured by the usage of clone gel in hydroponic systems and clone spray in aeroponic ones. Testers and adjusters will be placed in order to monitor the PH. The growth medium may be made of coconut coir, which is replaceable, or rock wool, which is the most appropriate solution or may be soilless. Any of the approaches mentioned above work efficiently in space.

Produce	*Quantity required*	*Hydroponic/Aeroponic*
Wheat	30.24 L	Hydroponic

		(Sprout Culture)
Carrots	4,550 kg	Aeroponic
Cucumbers	1,550 kg	Aeroponic
Onions	1,000 kg	Aeroponic
Spinach	1,000 kg	Aeroponic
Vegetables	10,000 kg	Hydroponic (Nutrient Film Technique)
Potatoes	5,500 kg	Aeroponic
Tomatoes	4,550 kg	Hydroponic (Nutrient Film Technique)
Cauliflower	2,000 kg	Hydroponic (Deep Water Culture)
Rice	3,500 kg	Hydroponic (Deep Water Culture)
Lettuce	4,780 kg	Aeroponic
Apples	1,312.5 kg	Aeroponic
Oranges	1,450 kg	Aeroponic
Strawberries, raspberries other berries	3,412.5 kg	Hydroponic (Deep Water Culture)
Watermelon	2,000kg	Hydroponic
Other fruit	3,000 kg	Hydroponic (Deep Water Culture)
Sugarcane	1,500 kg	Aeroponic

Meat and diary will be produced *in vitro,* meaning that the meat has never been part of a living animal but is generated from muscular cells and fibers. Fast growth will be ensured and a perfusion system as well, in order to keep the growing muscle nitrified.

In vitro meat presents a series of advantages. First of all, when fully developed, it will be cheaper than animal meat. Most of all, it is healthier. It will be 100% muscle and no fatty oils at all, while omega-3 fatty acids will be added. Moreover, IVM will not present influenza, mad cow disease or any other diseases. Diary products and eggs can be produced the same way.

DISTRIBUTION

All produce will be distributed throughout each residential module, where it will be provided to one of the module's public cafeterias or sold at low prices to private dining institutions. This assures that all food is prepared fresh, without any significant delay from production to consumption. Public cafeterias will serve food that is free of charge to residents at any point during the day. Residents will also be given the choice to dine at a private restaurant, or at café.

4. Waste Management

Classification

Unlike on Earth, the settlement will not have an abundance of natural resources to draw upon for production purposes. For this reason, it is vital that all possible efforts are made on the part of both the administration and the residents to reduce superfluous consumption, reuse anything that does not need to be immediately discarded, and recycle a majority of wastes. Since the term waste is broad, it first needs to be broken down into several groups of materials and substances that require separate avenues of treatment in order to be recycled.

Waste Group	*Treatment*
Paper	Heated and strained
Aluminum	Melted
Steel	Melted
Plastic	Melted
Batteries	Ground and acid neutralized
Glass	Melted
Textiles	Shredded and carded
Wood	Shredded
Electronics	Component separation
Organic	Compost
Human	Incineration

Paper

Undoubtedly, paper is going to be a very important staple for the residents of Bellevistat. However, there will not be a large supply of trees on the station, so traditional wood-based paper products will not be an option. Instead, a polymer-based synthetic paper will be used instead. This synthetic will be 100% recyclable, though it will need to be disposed of in proper receptacles. The paper collected in these waste receptacles will be sent into a separated processing facility where it will be melted down and then recast into pellets that will then be flattened out into sheets of paper. Infrequent shipments of the polymer required can be made from Earth as more paper is needed. This technique will be effective because it allows the citizens to use a higher quality product than normal paper and still be economic from a reusability standpoint at the same time.

Collection

All waste on the settlement will be discarded into separate, color-coded bins. Due to the necessity of recycling on the settlement, there will be a relatively large amount of bins instead of the traditional sole garbage can. There will be a separate bin for paper, metal, plastics, glass, organic, and miscellaneous wastes, such as textiles and wood. Battery bins will not be needed, since most residents will only be using rechargeable batteries for their appliances. However, this system of color-coded discarding stations will become one that integrates itself as part of the culture and lifestyle of the citizens. Sorting trash before discarding it will quickly become second nature to the inhabitants of the settlement.

Processing

Recycling will be a major component of the culture on the settlement. Rather than being an option, recycling will be the sole method of disposal for almost every type of waste.

Paper will be recycled just as it is on Earth. Marked paper recycling bins will be common throughout the settlement, both in public areas and in private quarters. The paper recovered in these bins will be shredded and then heated to separate the fibers. These fibers, forming a pulp, will then be strained, deinked, bleached, and mixed with water. The substance can then be dried to form new paper. Fortunately, paper usage will not be prominent throughout the settlement anyways. The lifestyle of a resident will be heavily integrated with electronics, such as tablets and screens, rendering paper minimally used.

Metals will also have their own bins throughout the settlement. The most common types of metal that will be recycled are aluminum and steel. These metals can go in the same recycling bins. This is because they can be separated during the recycling process with the use of magnets. Both metals, separated from one another, will be melted in order to be reused in new, recycled forms. Plastics will be recycled through melting as well.

Glass can be easily recycled through melting. All discarded glass will be stored in a closed facility until is needed. There, it will be ground into a mixture of coarse, crushed particles known as cullet. The cullet will be brought into a furnace to be melted and remolded for new applications.

The fibers of textiles can be reused as well. Recycled textiles, such as damaged clothing and sheets, will be shredded up to form large masses of fibers. Some of these fibers will be directly taken out to be used as insulation or stuffing for mattresses and blankets. The rest of the textile remains will be carded so that they can be spun into new cloth.

There will not be wood on the settlement, since there will not be an abundance of trees that can be used for the lumber. Most structuring will be done with metals, and furniture will predominantly consist of metals and plastics, among other polymers.

Not all waste on the settlement will be synthetic. Organic wastes will make up a large amount of the wastes on the settlement. These wastes will predominantly be used composted in order to fertilize soils found in public areas of the settlement. Human wastes will be incinerated to provide small amounts of additional energy, and elements such as nitrogen will be extracted to be given to aeroponically and hydroponically grown plants.

5. Atmosphere and Environment

Sky

In order to best simulate Earth-like conditions within the residential modules, every possible measure will be taken to emulate natural features and downplay the synthetic and technical nature of the settlement. This will help maintain a high resident morale. One of the most fundamental attributes of a terrestrial environment is a sky. It

establishes a sense of openness that contrasts the dismal feelings of confinement a metal ceiling would imbue in the residents. The ceiling of the residential modules, therefore, will serve as curved screens on which an accurate depiction of a sky will be projected, complete with an occasional clouds and a simulated weather cycle. Projectors will be located around the inner perimeter of the module and will be maintained through a control center located within the module.

Although weather events such as rain and snow will not take place, varying cloud cover will simulate such weather conditions visually. The ceiling will also contain strips of solar simulator lights to provide artificial sunlight to the residents. The sky projection will follow a day-and-night cycle that will undergo seasonal daylight hour variations in a manner very similar to that of Earth. Since the sky is projected, all residential modules and all areas within those modules will remain in the exact same time zone, eschewing any difficulties in communication across the settlement.

6. Transport

Human-Interior Transport

Bellevistat's design makes it optimal for human transportation around the settlement. The two inhabited modules are directly linked, through the shortest path possible.

Research and agriculture also require interference with scientists and engineers and are therefore linked to inhabitance. Mining and nuclear are fully atomized, but should any accident occur, linkage to these modules also exists. All aspects of manned transportation are either done through the aid of gravitational acceleration or Eddy Current based elevators.

Lenz Law Elevators

Bellevistat is an incredibly large space station with many components. Some of them are rotating while others are stationary, compounding the problem of having people move from place to place within the station.

For most of the population, the majority of life will be spent between the two habitation rings. As these two rings contain all residential areas, cafeterias, entertainment clubs, shopping centers, and business, the heaviest traffic will take place between them. Thankfully, these two rings will co-rotate in perfect synchronization, so facilitating transport between them can be enabled by the simple establishment of a series of large elevators. Six elevators will be spaced evenly along the circumference of the two rings, with an elevator placed every 100 meters.

The elevator tubes connecting the two rings will be made of aluminum while the elevators themselves will be rounded capsules made of a magnetic iron-nickel alloy. At each of the tubes' two ends where they connect to the habitation rings, there will be large circular electromagnetic clamps that hold the elevator steadily in place as people get on and off.

The elevator will operate based on the principle of Lenz's Law. The application of a magnetic force against the capsule counteracts the pseudo gravitational force and causes the "descent" of the elevator to

slow down such that the speed is approximately constant as opposed to accelerating. As the elevator reaches the opposite end of the tube, rings of electromagnets wrapped around the outside of the tube will turn on, increasing the strength of the magnetic field opposing the movement of the capsule. This will cause the capsule to slowly decelerate until it comes to a stop at the mouth of the tube where a second electromagnetic clamp will activate and firmly grip the capsule. As the elevator will experience forces in opposing directions, the people using the elevators will be strapped into seats as a safety precaution, although the risk of harm is low as Lenz's Law ensures that no significant acceleration will take place. Each elevator will be able to seat 7 people, and will have a maximum capacity of 12.

While the elevator will enable transportation between the two rings, there still remains a need for an internal transportation system. Each habitation ring will have a circumference of approximately 3,142 meters, so there needs to be an efficient way to get between any two points on the settlement. While walking paths will exist on the various levels of the habitation rings, they will not be sufficient for travelling long-distances. Therefore, the equivalent of a subway system will be constructed on the "bottom" of each habitation ring (on the surface pointing outwards from the center). As building and operating a train takes a good deal of space, the train will be on the outside of the ring as opposed to inside of it. A circular track of permanent magnets will wrap around the outside of the habitation ring, with eight adjacent train stations spaced equally around the circumference.

This unique flux tube configuration results in a phenomenon known as flux pinning: it will spatially lock the position of the train approximately two centimeters above the magnetic track. As gravity attempts to push the apparently unsupported train out into space, the configuration of magnetic flux tubes will allow the train to hover at a fixed distance outside the magnetic track. As the train starts and stops at the eight stations around the ring, guiding electromagnets will activate to either give the train a push forward or apply brakes on it externally.

7. Telecommunications

Communication is undoubtedly one of the most important issues to consider for Bellevistat. It is split into two categories:

1) Communication with Earth, mining operations, research teams, and other stations across the solar system.

2) Communication between the settlers within Bellevistat itself. In order to communicate with all people outside of the settlement, Bellevistat will be equipped with three large radio antennae. Each antenna, which will be made of lightweight aluminum, will be a spherical reflector with a diameter of twenty meters.

Each antenna would go on the outside of each of Bellevistat's major arms so that all three wide-angle antennae will always have all portions of the sky visible between them. Each antenna will not only be capable of receiving radio transmissions but it will also be capable of broadcasting radio transmissions within a large range of frequencies. Therefore, the antennae will comprise a major communications network whose main hub will not be the antennae but rather a computing hub located securely within the center of the ship.

The computer will autonomously regulate all transmitted and incoming signals, monitoring the signal quality so that data streams can be exchanged between antennae with no major hassles as the reflectors are forced to work with multiple streams at once. As for communications within the settlement itself, Bellevistat will utilize an extensive system of radio femtocells spaced periodically throughout all areas of all structures.

High-power femtocells, which resemble small cubes, can be placed along habitation corridors as well as inside all other spaces in which people with mobile cellular devices (which is to say, all of them) would wish to communicate with others. The advantage of femtocells is that instead of having one centralized tower which manages all traffic for you and is most likely quite a ways off, femtocells have a range of approximately ten to twenty meters so anybody would be close enough to a receiver to be able to get high-speed reliable-service Internet.

4. HUMAN FACTORS AND SAFETY

ACCOMMODATIONS

RESIDENTIAL MODULE

Appropriate housing will be needed for the 10,000 residents of Bellevistat to live comfortably and with high morale. To ensure optimal comfort, the residential module will be constructed to simulate conditions on Earth, with a projected artificial atmosphere emulating terrestrial day-and-night cycles as well as required amounts of synthetic sunlight. Grass will be common throughout the residential areas, as well as trees and streams. Apartment complexes and neighborhoods of homes will allow for communities to form, promoting resident socialization. This sense of community will be further augmented by the scattered installation of parks as well as shopping malls and other centers of entertainment, shopping, and socialization.

Houses will be distributed on the three layers of the inhabitation module, with ease of access to entertainment zones, public libraries, museums, or other facilities.

THE APARTMENT

The most basic unit of residence on the settlement will be an apartment. The apartments will lay out with studio floor plans, consisting of a bed, small kitchen, and living room space, as well as a full bathroom enclosed and off to the side. They will also include amenities such as a large window near the bed, a television, computer, and phone, as well as a simple closet.

The apartment is designed for single residents and couples without children, since they do not have the space or capacity of housing an entire family. The apartments will be laid out in multistory complexes located near social hubs of the residential module. They will also be located with an emergency medical facility and convenience shopping within close proximity.

The bedroom floor

Each floor of the apartment complex will consist of various long corridors of entrances into each dwelling. On the first three floors, the center of the apartment complex will consist of a social lounge for the guests of the apartments. The lounge will be open throughout the day, and the first two upper floors will have balconies that look down onto the area.

THE FAMILY UNIT

Once a couple has children, they will be relocated to a family unit within the residential structure. A family unit is a two-story dwelling with a living room, full bathroom, full kitchen, master bedroom, and bunk beds. It will include all the amenities of the apartment but will be more spacious and individual.
Three two-story family units will be stacked on one another to form a six-story, three-family building.

Long rows of three-family buildings will be constructed down avenues devoted solely to these structures. These lanes will be spacious, allowing for a front yard as well as a backyard.

A ROW OF THREE-FAMILY RESIDENTIAL UNITS

TOURISM

As the first large habitable outpost in the outer solar system, Bellevistat will undoubtedly see many tourists. While the economy of Bellevistat will prosper primarily from its business in construction, mining, and research, tourism will also contribute positively. People from Earth and other inhabited areas within the solar system will undoubtedly bring their currency to the Bellevistat, but more importantly, they will take news and sights from Bellevistat back home. The Bellevistat Board of Tourism will strive to leave a positive impression upon the minds of tourists so that they will return with their money, consider business with Bellevistat, and possibly even decide to become a citizen of Bellevistat.

Within Habitation Ring A, there will be a small luxury hotel. It will contain rooms that are larger and more lavish than the ordinary housing quarters. Both citizens of Bellevistat and tourists can pay to rent a room and enjoy the hotel's facilities such as private spas, restaurants, and recreational areas.
Tourists can pay for special access and assistance with Bellevistat's zero-g facilities. To any normally earthbound tourist, the chance to experience and enjoy microgravity will be a memorable one that will certainly be an attractive feature.
As any tourists visiting the outer solar system will most likely be committing themselves to a long-term trip, they will have the opportunity to participate in long but exciting adventures. The most popular and most anticipated option for tourists will undoubtedly be the cruise of the Jovian planetary system, which will involve fly-bys of the Galilean moons, a visit to Odin Base on Callisto, and several orbits around the

gas giant itself at varying latitudes. The cruiser that will ferry the passengers will sport a very thick, dense hull designed to protect the tourists from the intense doses of radiation found within Jupiter's powerful magnetic field.

The entire trip will last several weeks, and will offer stunning views available nowhere else in the solar system. Another tour that will be offered is a trip to the main asteroid belt in which tourists can visit the extensive mining facilities set up in orbit aboard a large cruiser resistant to strikes by small asteroids. While exhilarating, this trip will certainly be associated with danger if the tourists are not careful, even though the density of asteroids within the outer asteroid belt is quite low. These two tours, along with external tours of the settlement itself, will be the largest tourist attractions that Bellevistat will offer.

LEISURE

The two habitation rings of Bellevistat will be designed with many facilities built for the recreation of the settlers.

THEATERS

First, there will be theaters in which films are screened for public viewing. The movies will be beamed from Earth where they can be recorded and saved for storage onboard Bellevistat, producing an impressive cultural library that citizens will have access. Brand new films will have tickets at public shows while old films can be requested from a central distribution center and viewed at home for a small fee.

SHOPS AND CAFÉS

On the central alley already introduced, café's and small shops encourage entrepreneurship among the Bellevistat -inhabitants, giving a sense of community, friendship, and helping people get to know each other, make friends, and feel comfortable and safe in a new environment.

LIBRARIES AND MUSEUMS

Libraries will serve as a quiet study place for students in the Bellevistat University, as well as an entertainment zone for lecture amateurs. Although Bellevistat will not provide actual books, 100 devices similar to the popular Kindle will serve as databases for thousands of operas. There will be 10 libraries available throughout Bellevistat, 5 on each inhabitance ring.

Bellevistat will also be endowed will a museum, reminder of Earth, its history, and our starting point. It is most important that Bellevistat-born children understand their heritage.

PARKS

Public parks will be placed sporadically throughout the habitation rings with gardens and play areas for children. Meant to mimic the natural surroundings of Earth, they can serve as places in which people can congregate for picnics or any other activities with a nice view. Bellevistat will not just isolate itself as a scientific outpost, for it is important for a community to have a shared culture in order for it to feel united. A Society of Art will be instated that brings together writers, painters, directors, and other artists of all kinds to create unique art and produce a culture for Bellevistat. Trained by Bellevistat University's art

program, the Society of Art will put on regular stage performances, musical concerts, art exhibitions, etc. Together, they will contribute to a vibrant community onboard the settlement.

A public park at night

CONSUMABLES

Shipping medicine from Earth is not an option, considering the huge distance between Bellevistat's location and Earth. Conclusively, the settlement must be equipment with all the necessary prime material to produce all needed equipment.
Thankfully, asteroid materials such as minerals will aid the production of medicine, electronics, and any metal-based component, while interior plants will produce cotton and textiles (agriculture modules are widely distributed all through the settlement).
All other requirements will be satisfied chemically, in Bellevistat's multiple production, deposit, agriculture, mining and industrial zones.

HEALTHCARE

ORGANIZATION

Providing immediate medical assistance to all Bellevistat residents will be a priority. The healthcare system will consist of a primary organization that will branch off into separate hospitals standardized in their practice. The primary organization will be known as RHMS, or the Resident Healthcare Management Service. It will be an overall healthcare administration hub that will provide training to all physicians and

monitor all data provided by the individual hospitals. The organization will also oversee all medical research-taking place on the settlement.

A hierarchy of medical care branching off the RHMS will exist in order to provide all denizens with both emergency responses and long-term care. Each residential area will have one predominant medical institution. This facility will serve primarily as a hospital for more serious cases, but it will also provide a certain extent of primary care if local physicians are not fully confident in their diagnoses or prescriptions. The facility will also serve as the primary center for research within that structure.

The healthcare system will also include local health clinics within proximity of every residential area. These facilities will be areas or primary care and will also include a pharmacy to expedite the process of medical treatment. Individuals who seek a free check-up at any time at the clinic will either be treated locally as necessary or referred to the hospital for more specialized treatment.

Primary Care

The local health clinics will serve as checkpoints for medical treatment. They will filter serious medical conditions to be sent to the hospital while treating milder conditions within the clinic. The staff of local clinics will include predominantly primary care physicians along with nurses, pharmacists, an anesthesiologist, and a general surgeon.All residents will be required to undergo a brief, routine medical checkup bimonthly, since these check ups are integral to determining individualized meal plans. The checkup will assess the mental and physical health of the residents. The patients will also undergo short chemical tests to provide more thorough information on their current health. The primary test will be a simple urinalysis. This analysis will test for the internal levels of substances such as various proteins, hormones, ions, trace metals, and glucose. Such a test will be instrumental in assessing the dietary needs of the patient. Indeed, the data will be entered into an integrated information bank that will be cross-referenced with dietary planning algorithms to plan an individualized dietary plan of action for the next two months.

The primary check-up, however, will also need to screen for possible disease in the patient. Many serious conditions can start asymptomatically and rapidly progress without any physical indication until it is almost too late to treat (e.g. cancer). The clinics will, therefore, use a relatively novel method of blood screening using carbon nanotube resonance spectroscopy. Blood serum will be isolated via centrifuge and placed in a well where the serum will be taken up by a micro capillary array due to capillary action.

Specialized Care

If the primary care physician is able to, with the aid of analytical devices and software, determine that the patient has a medical condition that cannot be fully treated in the local clinic, the resident may become an inpatient of the hospital. This will allow for them to receive specialized treatment for their specific condition.

The hospital staff will consist of a significantly greater number and variety of physicians. The facility will be broken down into various wards with physicians trained specifically in that field of medicine. The hospital wards will be divided into separate trauma, cardiology, ENT (ear, nose, and throat), gastroenterology, neurology, general surgery, intensive care, maternity, nephrology, oncology, ophthalmology, psychiatry, orthopedics, and pediatric wards. In addition to these divisions, the hospitals will also contain internal pharmacies and a separate yet connected research facility where medical researchers will work on the development of new medical techniques, procedures, devices, and drugs.

PHARMACEUTICALS

The settlement will need a large supply of drugs and other medications in order to provide for the all residents. The initial medications will be provided from Earth as a payload. However, very quickly into the age of the settlement, this supply would run out. Therefore, it is imperative that plants are developed to produce sufficient quantities of medications to provide to every inhabitant. Since all medical care aboard Bellevistat is free, it is important too that the production of drugs is extremely efficient.

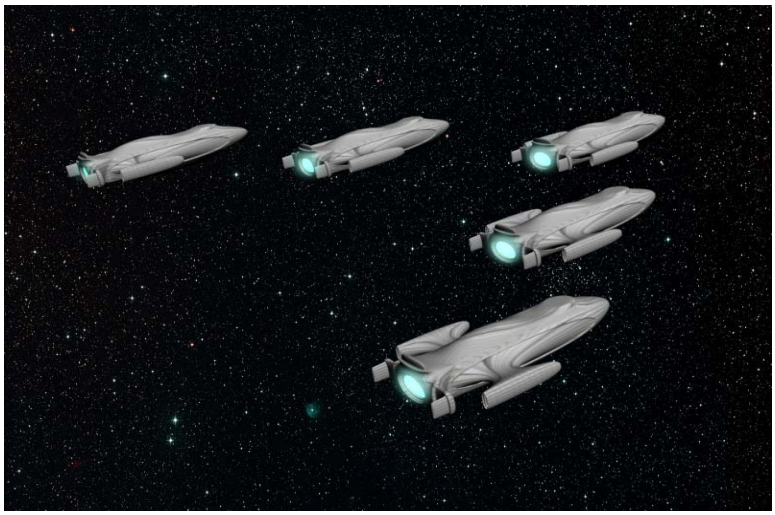
Drug manufacturing plants will be found in the center of the settlement, where they will operate in microgravity conditions. Such conditions are favorable for any manufacturing plant, since the weightlessness of all components makes transportation efficient.

TREATMENTS IN MICROGRAVITY

The majority of medical care will be given in a 1g environment, since nearly all of Bellevistat's medical facilities are in the residential sections. Most treatments require a regular environment as well, since any shift in gravity should change the state of many bodily systems. However, a lack of gravity can be taken advantage of in certain circumstances. Therefore, it is important that the medical facilities of the settlement take advantage of microgravity therapeutic procedures.

On Earth, a common relief for chronic back pain is a swimming pool. Back pain is predominantly caused by a large amount of pressure on the spine, which can push down on disks or even pinch nerves. Pain from this ranges from minor discomfort to severe pain. One of the most important ways to combat this pain is through regular exercise. However, many individuals with back pain tend to shy away from any kind of moderate to intense physical activity due to lack of spinal support and high pain levels during such activity. For this reason, many patients turn to swimming pools as ways to relieve both immediate pain and chronic pain. Buoyancy allows a human immersed up to the neck in water to feel 90% weightless. In doing so, they are relieved of a large amount of their back pain. The spine is no longer forced to counter the full force of gravity as is necessary out of the water. Instead, the bones are able to spread out without a need to be compressed downwards together. The patient therefore feels immediate relief.

Activities performed in a lack of gravity also benefit patients over long periods of time. Being in an environment of minimal gravity allows them to perform exercises they would otherwise never be able to perform in normal gravity conditions. Without a compressed spine, exercise is painlessly performed, which furthermore reduced the overall severity of chronic back pain over time.Individuals on Bellevistat with chronic back pain will be allowed to undergo microgravity therapy sessions within the settlement. They will be brought into small, temperature-controlled chambers to relax in weightlessness while feeling the direct therapeutic effects of the lack of gravity.



Delta formation

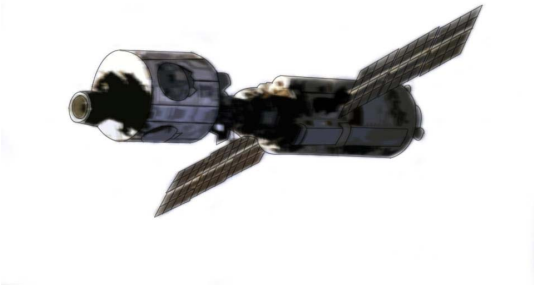
Microgravity therapy for chronic pain is more effective than a swimming pool because it almost completely removes the weight of the individual from the spine, increasing comfort and relief.

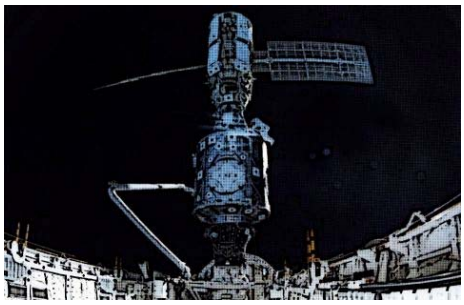
TRANSPORT

Undoubtedly there will be people who wish to head to the Earth, perhaps on vacation or for business. As Earth will be a high frequency trading partner, there will be one ferry cruiser that goes to Earth and comes back to Bellevistat once a month.

It will also make a stop in lunar orbit before coming to near-Earth orbit, where all disembarking passengers can wait in an orbital spaceport as they pass through customs and immigration before they are received on Earth's surface. Depending on the current orbital positions of other bodies such as the asteroid belt mining bases and Mars, the ferry may stop there, as well; however, there are no guarantees, as the primary objective is to get to Earth.

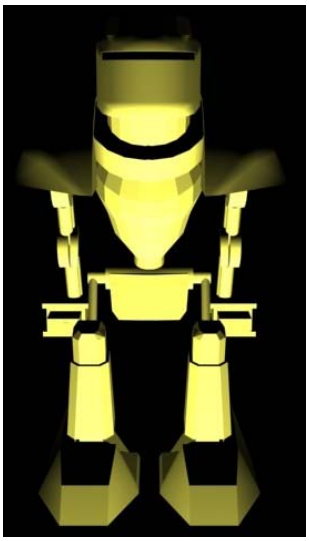
Smaller ships will be sent to other places within the solar system such as these at a less frequent rate. Similarly, transports will be sent to the Jovian planetary system on a regular basis for scientists visiting Odin Base as well as the other scientific projects within the station. These transports will require much more shielding to combat Jupiter's lethal magnetosphere.





5. AUTOMATION DESIGN AND SERVICES

Bellevistat is a fully automated module, with telescopes orbiting it, the Moon and GEO on the lookout for asteroids, an extensive fleet of space ships, rovers, mining robots, all presented throughout the settlement.



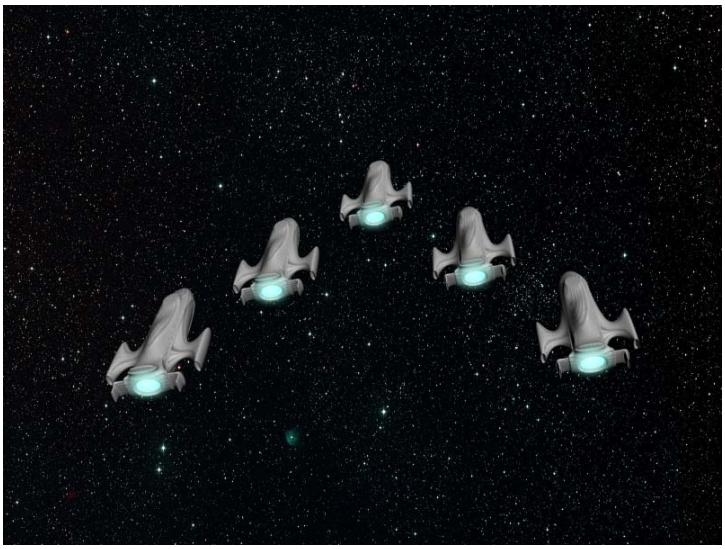
Droids manage cleaning and emergency situations, while a central computer handles all electronics aboard. In order to prevent chaos generated by an improbable general breakdown, the main computer is split up in five smaller units, distributed in the settlement. All connections are made through optical fibers, in order to optimize the signal (Wi-Fi being highly inefficient).

Robots serve a great deal of purposes on Bellevistat, ranging from defense mechanisms (handle epidemics, fire hazards, human dangers, aid in extreme medical care, etc.) to debris collection, asteroid collision prevention, with construction robots moving Bellevistat (and keeping it) in its stable orbit. (Bellevistat's robotics section includes elements such as Machine Learning and electronics).

Robotics

When regarding robots, it is vital to take into consideration the engineering components, power source, electrical sources, linear sources, air muscles, piezo motors, elastic nanotubes, environmental sensors, human-robot interaction, speech recognition, robotic voice, motion and kinematics, sensitivity, touch, vision, mechanical grip, and a third category, locomotion, based on wheels, snake-model, hopping and possibly the development of walking and climbing techniques.Bellevistat will use five main types of robots, a defense-specialized robot, a human-interaction cleaning robot, an android specialized in relationship with humans, a robot used in construction and a spider-like robot for mining.When discussing robots, programming must be considered as well. Artificial intelligence must be used in order to recreate a human conscience, a way of thinking, and a resemblance between the connections of the two brain hemispheres – in humans which

suffered accidents and the two hemisphere's aren't connected anymore, mathematical tasks can be easily accomplished, whereas simple chores and decisions as the ones made when shopping may seem impossible as all objects appear to be the same.



A robots with slight improvements in conscience simulation and AI is SOINN, which can pour water and add ice – it may not seem revolutionary, but SOINN can decide whether to put the bottle down and add ice, and which to use first, etc. Bots will be programmed into making decisions based on the information available, observation and analysis of mediums and environments.It is expected that until the construction of Bellevistat, AI will be improved.

Automation for mining

Mining, as the preparatory phase, is one of the most important phases as it funds the construction of Bellevistat. The only investment will be the construction and launch of the robots and the exoskeleton of the settlement. From that point on, materials and money for other parts and components will be obtained when mining asteroids similar to Amun, described in the Defense part of this episode. Mining will be done in the Near Earth asteroid system, on the moon, and in Defense eventualities, in the case an asteroid approaches the settlement and proves threat.

In order to optimize the mining procedure, the robot shall be perfectly and most accurately adapted to an asteroid-like environment. Moon-buggies shall be used as scouts on the Moon and on larger asteroids.

Component type	Components	Description
Engineering components	Power source	Nuclear batteries
	Electrical motors	DC motors
	Elastic nanotubes	Artificial muscle technology
	Muscle wire	Contracts slightly (5%) when electricity runs through it
Environmental sensors	Tactile info	Less tactile information than in human

	Speech recognition	Personal bots recognize owners voice
	Robotic voice	adaptation, reasonably close to human voice
	Grippers	two fingers
	Computer vision	Optics
Locomotion	Wheels	May be used
	Snake-model	Adaptation for asteroidal environment
	Hopping	Adaptation for asteroidal environment
	Walking	Improvement stage

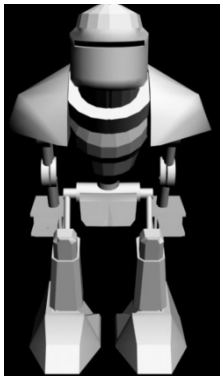
The table above fully presents the characteristics of a mining robot, and will do so for every major automatization chapter.

Automation for construction

Component type	Components	Description
Engineering components	Power source	nuclear batteries
	Electrical motors	DC motors
	Elastic nanotubes	Artificial muscle technology
	Muscle wire	Contracts slightly (5%) when electricity runs through it
Environmental sensors	Tactile info	No tactile information
	Speech recognition	Not necessary
	Robotic voice	Not necessary
	Grippers	Multiple arms endowed with grippers
	Computer vision	Optics, thermal sensors, radar
Locomotion	Wheels	May be used
	Snake-model	Adaptation for asteroidal environment
	Hopping	Not necessary
	Walking	Improvement stage

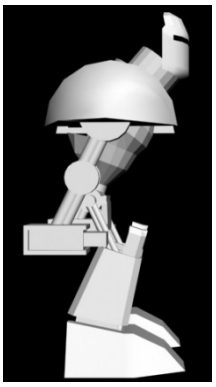
Construction is a most important part, as it must be perfectly completed and without any faults. In order for this to be ensured, construction will be primarily realized by robots, as space is a

dangerous environment for human, robots provide a much faster completing of tasks in a safer, more secure way. A construction robot will have multiple arms endowed with tools and robots will be specialized into fixing solar panels, securing construction panels, etc.It is vital that these are programmed on clear tasks, and are made as efficient as possible.



Automation for defense

Defense may be regarded to as interior threats defense and exterior defense. Exterior defense from any damage or malfunction is most important, vital for the success of space inhabitation. Therefore, an accent will be put on this.Defense robots are impressively big and large in dimensions. They are specialized on domains such as fire protection, asteroid capturing, etc.



Probably one of the most important sectors is asteroid catching as it provides resources, money and materials for Bellevistat. Therefore, it may be considered as they base business resource and an active domain for both jobs coverage on multiple living costs.

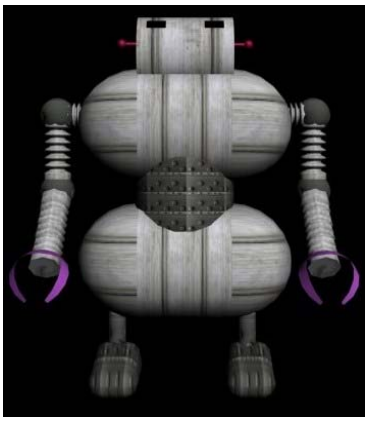
Component type	Components	Description
Engineering components	Power source	Nuclear batteries
	Electrical motors	DC motors
	Elastic nanotubes	Artificial muscle technology, better than air muscles
	Muscle wire	Contracts slightly (5%) when electricity runs through it
Environmental sensors	Tactile info	Very good tactile sensors, fine olfactive glands
	Speech recognition	Used in detecting humans in emergency situations
	Robotic voice	Resembles human voice
	Grippers	Multiple arms endowed with grippers
	Computer vision	Optics, thermal sensors, radar
Locomotion	Wheels	Basic locomotion system
	Snake-model	Not necessary
	Hopping	Not necessary
	Walking	Second most used locomotion system

Automation inside Bellevistat:

Automation inside Bellevistat must cover plant harvesting, cleaning, help and direction providers and house cleaning.These robots will mainly share similar components, but are very different in both construction and appearance.

Component type	Components	Description
Engineering components	Power source	Electric batteries
	Electrical motors	DC motors
	Elastic nanotubes	Artificial muscle technology, better than air muscles
	Muscle wire	Contracts slightly (5%) when electricity runs through it
Environmental sensors	Tactile info	Very good tactile sensors, fine olfactive glands
	Speech recognition	Used in detecting owner and obeying requests
	Robotic voice	Resembles human voice
	Grippers	Human-like android arms
	Computer vision	Optics
Locomotion	Wheels	Basic locomotion system
	Snake-model	Not necessary
	Hopping	Not necessary
	Walking	Second most used locomotion system

When discussing interior need robots on Bellevistat, three sub-categories must be brought up. An android will cover human sector, assuming future developments in AI and robot conscience will be made by that time. A house cleaning robot will be available as well, helping solarisiens with chores and taking care of children, teaching them basics. Finally, harvesting robots will be similar to the machines used today in agriculture, and will be endowed with any future developments made by that time.



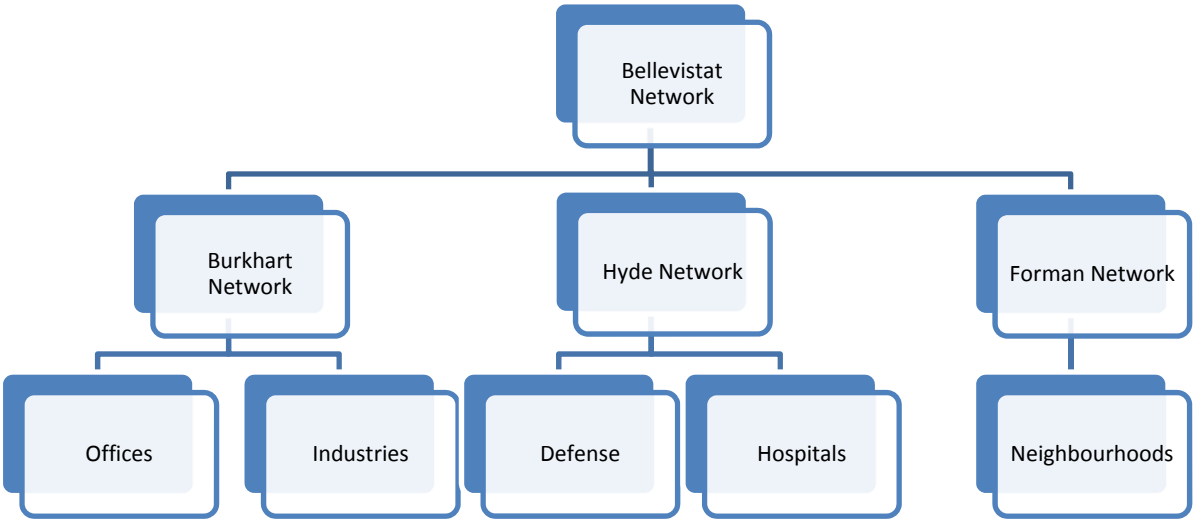
Bellevistat Central Robot Energy and Automatization Management-SCREAM

All robots on Bellevistat will be produced and repaired by SCREAM. They manage energy resources, repair damaged robots, help with pieces construction and, most importantly, monitor all technological activity on Bellevistat.

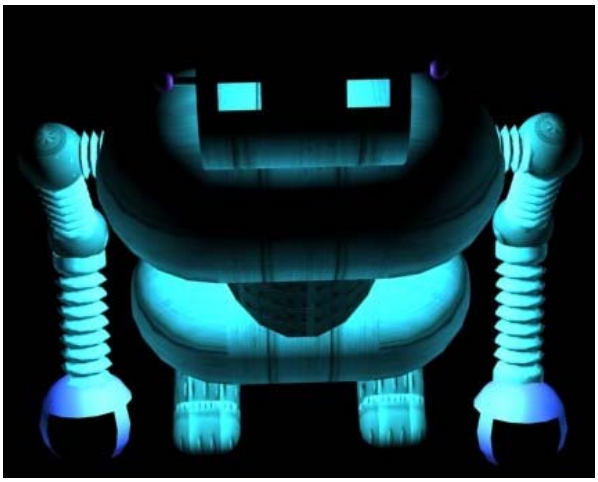
Technological activity ranges from Internet, personal computers, personal houseware, electrical ware, robots, Wi-fi, electronical management in malls, museums, etc., and any automized system on Bellevistat. Personal computers, personal and all electric houseware is designed and built by SCREAM, and further distributed throughout the system in special, designed shops. A thorough record of all the machines distributed in kept. Electronical management and all user interfaces, Bellevistat e-mail, etc., is created by software engineers in Bellevistat Industries.Robots make a most important sector, and Wi-fi and Internet access is monitored constantly and created by SCREAM.No disruption of Internet or Internet based systems will have place, as the settlement is perfectly insulated from solar flares or any other threat to Internet connectivity.

Communications

Communications will be fully covered by a complex Wi-fi and ad-hoc Wi-fi networks for computers. Optical fiber will not be used, as it would imply the use of massive resources and maintenance for both the fibers and the panels covering, etc.. All signals are transmitted through electrical systems.
Moreover, computers may interconnect with duplex systems, etc. as they wish.
Wi-fi routers will be placed at every 20 m. Networks are secured with WEP (Wired Equivalent Privacy).



Burkhart is the short name for Business, Offices and Industries main network
The Hyde Network is used for Defense, Hospitals, etc.
The Forman Network is used for Residential networks.
The scheme above applies for each torus. All the systems are controlled by Bellevistat Network central computer. The communications system functions independently from the robot control system.



6. SCHEDULE AND COSTS

Labour Expenses		
Domain	Number	Final Salaries
Engineers	1000 · 20 years · salary	$2 491 000
Aerospace Engieers	2000 · 20 years · salary	$2 491 000
Doctors	50 ·20 years · salary	$300 000 000
Financial Advisors	100 ·10 years · salary	$20 000
Counselors	100 ·10 years · salary	$20 000

FINAL COST LABOUR EXPENSES: $305,022,000

Materials			
Material	Layer thickness	Quantity	Price
Ceramic plates 5$ / kg	0,2m	505 722,4 m^3	$5 057 224 000
Reinfroced C-C $10/ $\boldsymbol{m^2}$	0,17m	~429 064,04 $\boldsymbol{m^2}$	$429 0640
Al, Ti, Mg alloys	0,15m	379 291,8 m^3	Total Al+Ti
Aluminum $1.43/kg	0,15m	379 291,8 m^3	$542 387 274
Titanium $12.35/kg	0,15m	379 291,8 m^3	$4 684 253 730
Carbon fibres	0,3m	758 583,6 m^3	$14 519 290 104

$11 / kg			
Aramid 37.6/ $\boldsymbol{m^2}$	0,1m	2528612 m^2	$95 075 811.2
Kevlar 37.6/ $\boldsymbol{m^2}$	0,1m	2528612 m^2	$95 075 811.2
Beta Cloth	0,7cm	1 770 028,4 m^3	Could not be found
Sealant gel $53/ $\boldsymbol{m^2}$	0,1m	25289771.42 m^2	$1 340 357 863
Solar Photovoltaiv Cells	-	780800 m^2	$19 520 000

FINAL COST of MATERIALS: **$26,357,475,234**

Interior Expenses		
Interior Expense	Quantity	Price
House Construction	3000	$300 000 000
Hospital Costruction	10	$10 000 000
Transport Sequence Constrcution	-	$ 2 000 000 000
Entertainment	-	$20 000 000
Bellevistat Zoo	1	$2 000 000
Bellevistat Observatory	3	$3 000 000
Parks, etc.	30743.4m^2	$439624.9

FINAL COST INTERIOR EXPENSES: $23,354,396, 200

Construction and Research Expenses		
	Quantity	Cost

Falcon Heavy	10	$4 350 000 000
Falcon 9	30	$1 500 000 000
Structure	-	$150 000 000 000
Nuclear Power Plant	2	$ 14 000 000 000
Research	-	$2 000 000 000
Control and Communication	-	$2 000 000
ELI	-	$10 500 030
Robots	2000	$2 000 000 000
Moon and Asteroid Mining	-	$25 000 000 000
Unexpected Expenses	-	$10 000 000 000

CONSTRUCTION AND RESEARCH EXPENSES: $**208,862,500,030**

TOTAL BELLEVISTAT COST: $258,574,371,464

During the first years, the costs will be the highest, as it is the phase where all the robots will be manufactured and the processes required to produce the main parts of the settlement will take place. Asteriods will start to be mined and the metals transformed into larger pieces that will later be assembled. By the time the external structure is complete, money will be spent on the interior design, which includes building houses in order to suit all the population, creating all the facillities required for a normal life, as well as on the missions which will bring human beings to Bellevista.

In the later stages, the last 3 years, the settlement will prepare to become financially independent. It will be the period where all things come to the end, Bellevistat is getting ready to host its inhabitants for the next decades. The lowest amount of money will be spent in this period, as the last preparations and assemblies are made. By this time, we will have all the population settled, and all the systems will be almost prepared to start functioning. At this point, the economic function of a space settlement starts to show off and money will be

obtained by selling certain materials obtained from extraterrestrial sources which are to be found in a quantity higher than needed.

7. BUSINESS

I believe there is a completely new and incredible domain in human evolution, and that is space. Space is now to us what the Atlantic Ocean was to Christopher Columbus. A new horizon. Therefore, the future in business, evolution and expansion consists first of all in asteroid mining. Asteroids are mainly all around us, and, unlike in Star Wars, they are not our enemies, and instead of simply destroying them, Bellevistat uses a whole new philosophy, using asteroids as the primary source of money in order to cover costs.

Most Near Earth Asteroids, Great Belt Asteroids, etc. reveals asteroids rich in metal and other substances, while no legal issues (such in the case of terraforming the Moon, Mars or building anything on a surface) constrain us. Bellevistat must ensure coverage of all costs in construction and further living expenses, as well as repairs, research or further space exploration.

Therefore, all space resources available must and will be used. A wide range is available, from Lunar Mining, Space Exploration, Hydrogen and Oxygen Management for Fuel-HOMF and, probably most efficient of all, Asteroid Mining.

Apart from being a great opportunity for obtaining resources, rather infinite and various metal, substances, etc. being available, the domains above may become Business Sectors of Bellevistat Industries, and will offer thousands and thousands of jobs. Progress in technology ining of asteroids will take place by following the next steps: localization of asteroid, telescopic spectroscopy, profit calculus, mining, sending back to Earth.

The first two parts blend in each other, localization being realized with the help of telescopic spectroscopy, which analyses the sunlight reflected by the mineral grains on each asteroid, and thereby determines the average composition. More than 1000 asteroids have been discovered this way. The profit brought by each asteroid depends on the quantity of metal and platinum-like metals. Mining process was already described in Episode One. Materials will be purposely crashed to Earth is small quantities or be deposited on Moon's orbit in order to use less space. Material obtained this way is most likely to be used in Bellevistat' construction.

In December 2006, a powerful blast of hydrogen atoms lasting for 90 minutes was detected by NASA, with pure oxygen atoms flowing (heavy irons being delayed because of the Sun's electromagnetic field). Such a powerful blast, one of the most powerful explosions, leaves remnants of hydrogen atoms on satellites, etc. such as the hydrogen traces found on the Moon from the solar flares.

Finally, hydrogen being one of the primary sources of fuel in chemical thrusters, further research in capturing hydrogen atoms resulting from similar blasts would be both extremely cost effective and useful, considering hydrogen as a green fuel source, and taken into account it's effects on Earth's economy.

APPENDIX A

Operational Scenario

Safety is a crucial component of Bellevistat's approach to creating the best environment possible for its inhabitants in outer space.

In the event of a hull breach at an interface between two residential areas, the following procedure will take place. Emergency barriers will be lowered along the entrances and exits of all modules in Bellevistat, effectively locking down the entire station and isolating all modules to prevent the spread of depressurization. Instantly, a team of autonomous repair robots will be sent into active duty; one such team will exist within each individual module. The robots will be armed with a fast-acting liquid polymer held within high-pressure spray guns that will instantly clog up the hole in the hull and harden to prevent further air loss. Meanwhile, all citizens will be directed via emergency lights on the ground toward specified areas which will hold breathing masks just in case the ambient pressure is decreased too much before the repair team can stop the leaking of gas. This is just a precautionary measure however, as due to the large volume of the modules and the quick response of the autonomous repair team, this scenario is believed to be extremely unlikely. Once the hull has been sealed up temporarily, life inside the module can return to normal while teams of repair robots on the outside of the station create a pressurized bubble around the hull breach, remove the polymer sealant, and safely reapply the various layers of shielding in the hole.

Another scenario that Bellevistat will be prepared for is the possibility of an internal explosion that releases heat and toxic gas within an industrial complex. Just like as in the previous scenario, emergency barriers will seal off all openings, again placing all modules of the settlement under lockdown in order to isolate the effects of the explosion. This time, even larger fleets of autonomous responders will be sent out (again, these teams are located within each module). Transport robots will find any injured workers and quickly take them back to mobile autonomous medical centers that will treat wounds and burns on the spot without wasting further time. Firefighting robots will be sent in with highly pressurized polymer foams that will suffocate any fires created by the explosion. Meanwhile, water jets located at the tops of the structures will have guidance systems and will aim directly into the heart of the fire, putting it out as quickly as it is started. Again, citizens will be guided towards breathing masks in order to prevent the inhalation of toxic gases. Together, all of these precautions will allow the damage to be minimized and ensure the safety of the workers in the industrial center. Afterwards, heavy duty construction teams will clear any debris and make more permanent repairs to return the machinery and structures to their original forms.

APPENDIX B

Residential Design

Our residences usually have one level in order to maximize the number of houses, and most of them have access to the roof. Here, our residents may place grass or benches or even playgrounds for their children. Based on the access on the roof, the number of inhabitants and their preferences we have 6 models:

Single's House:

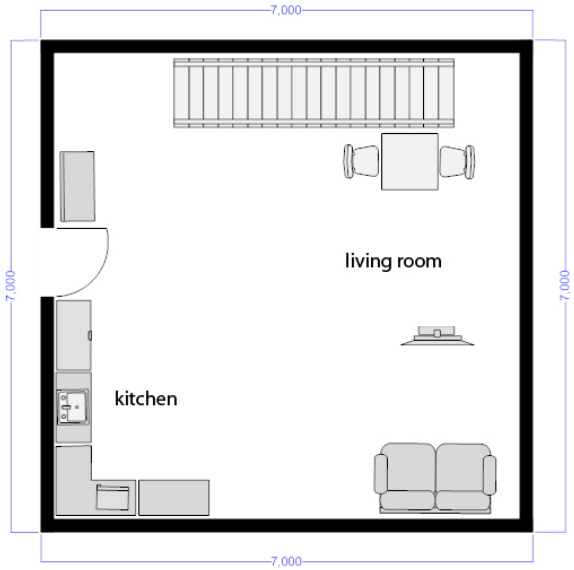
Access on the roof: yes

Number of inhabitants: 1

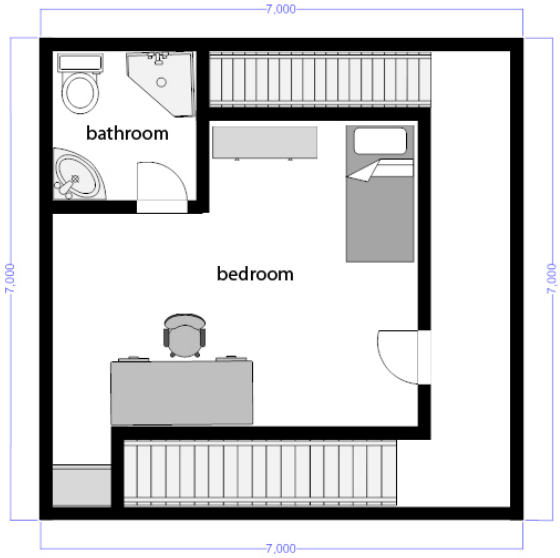
Area:

-ground: 49 m² (≈527.4 sq.ft.)

-first level: 49 m² (≈527.4 sq.ft.)



Ground



First floor

Couples' house with access on the roof

Access on the roof: yes

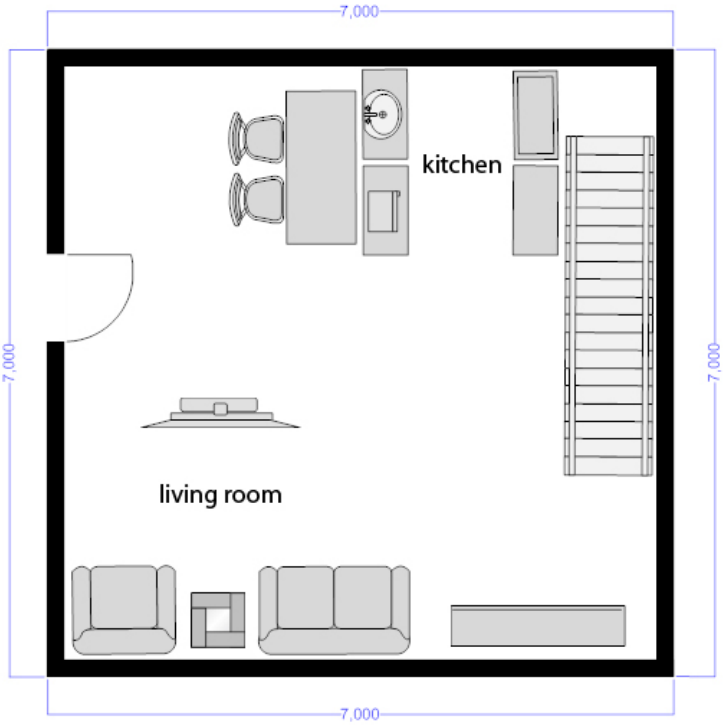
Number of inhabitants: 2

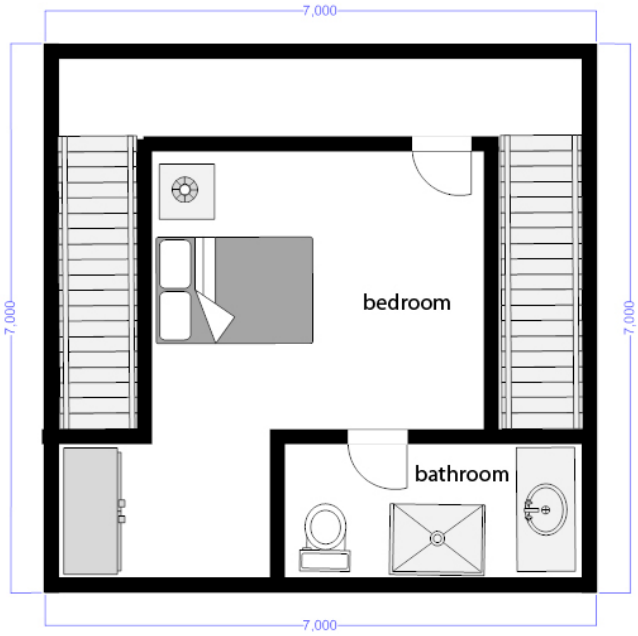
Area:

-ground: 49 m² (≈527.4 sq.ft.)

-first level: 49 m² (≈527.4 sq.ft.)

Ground





First level

Couples' house without access on the roof

Access on the roof: no

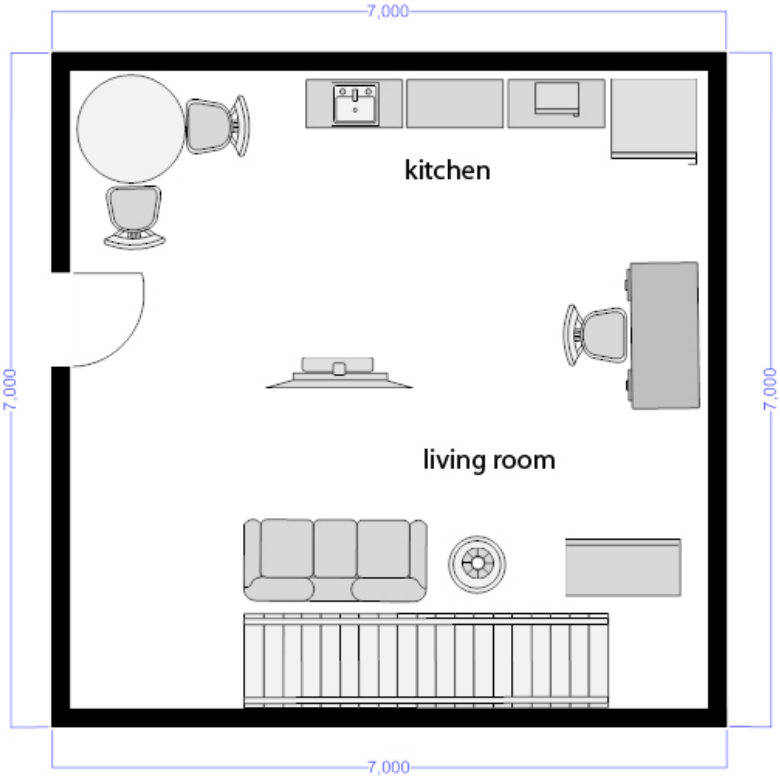
Number of inhabitants: 2

Area:

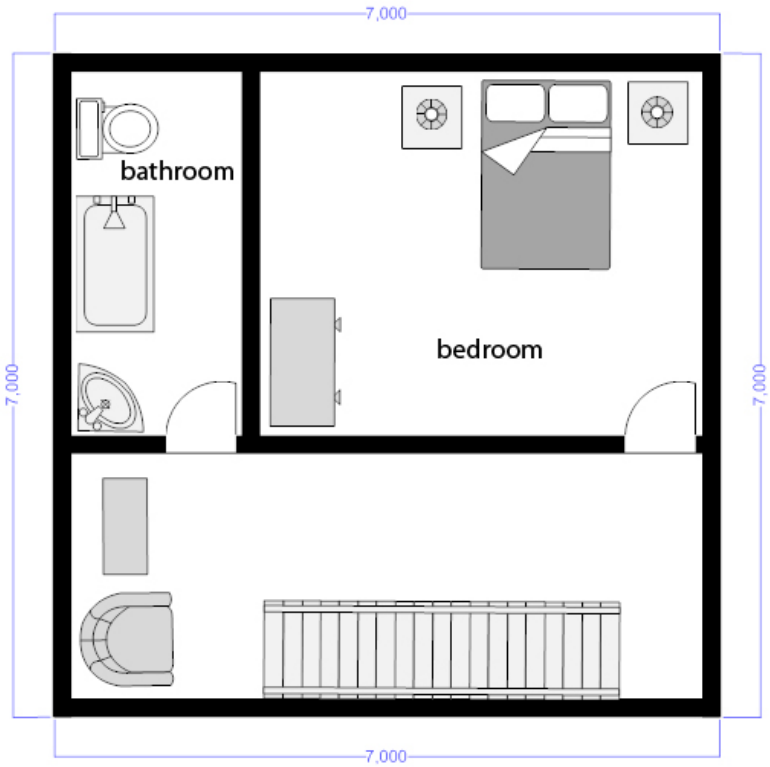
-ground: 49 m² (≈527.4 sq.ft.)

-first level: 49 m² (≈527.4 sq.ft.)

Ground



First floor



Family's house

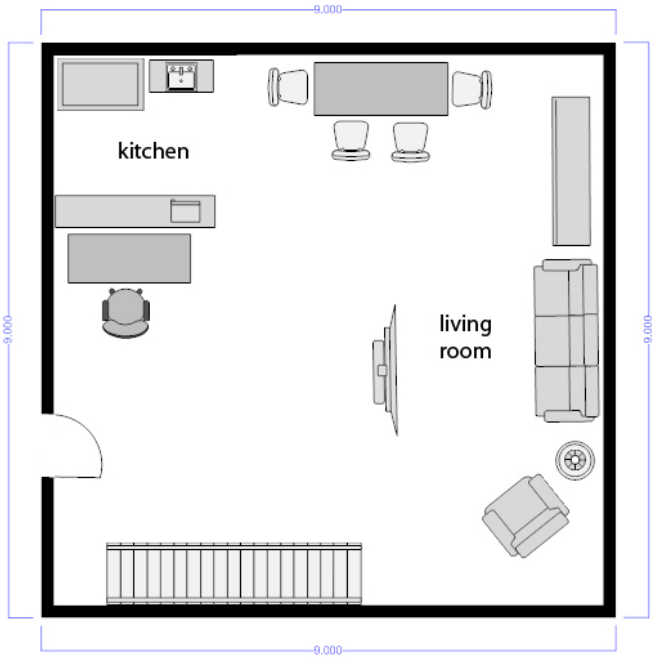
Access on the roof: yes

Number of inhabitants: 4

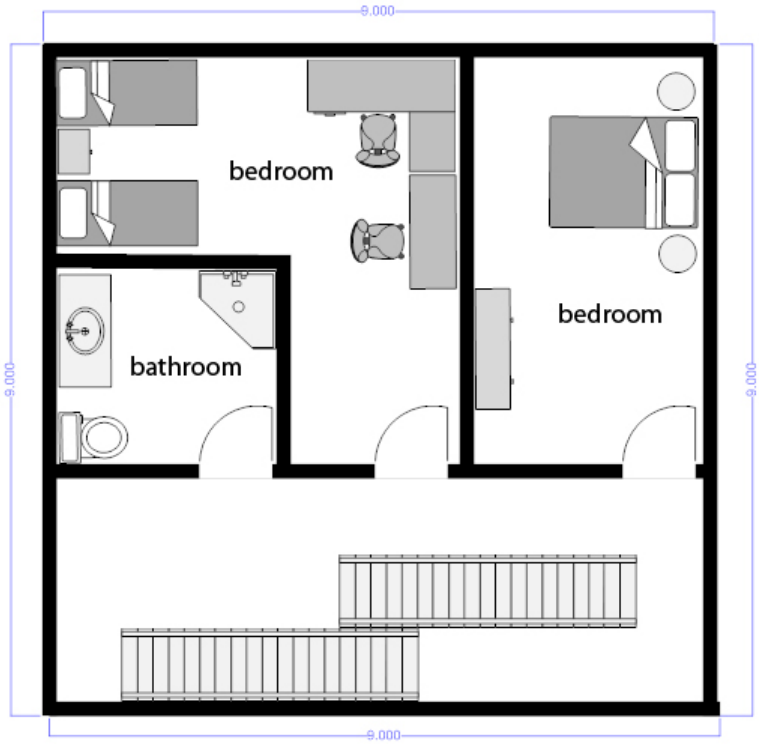
Area:

-ground: 81 m² (≈871.9 sq.ft.)

-first level: 81 m² (≈871.9 sq.ft.)



Ground



First level

Family's house

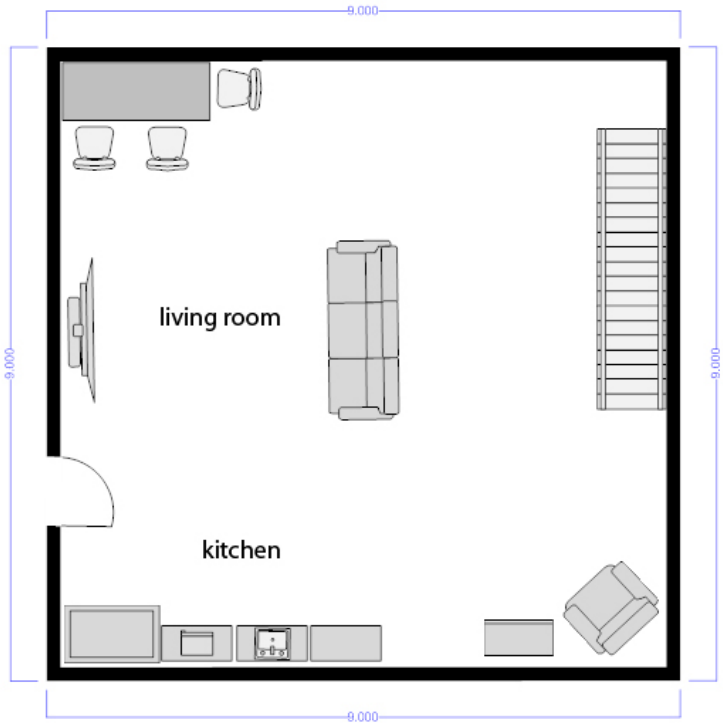
Access on the roof: yes

Number of inhabitants: 3

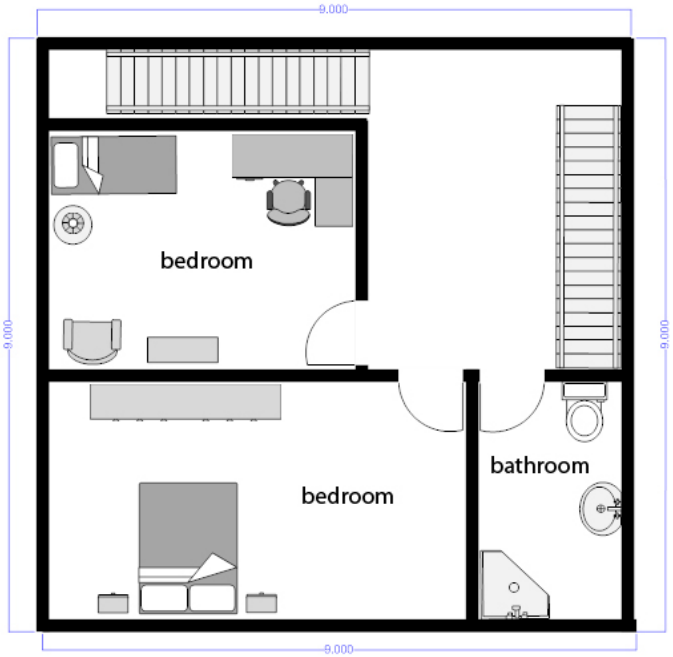
Area:

-ground: 81 m² (≈871.9 sq.ft.)

-first level: 81 m² (≈871.9 sq.ft.)



Ground



First level

Family's house (different design)

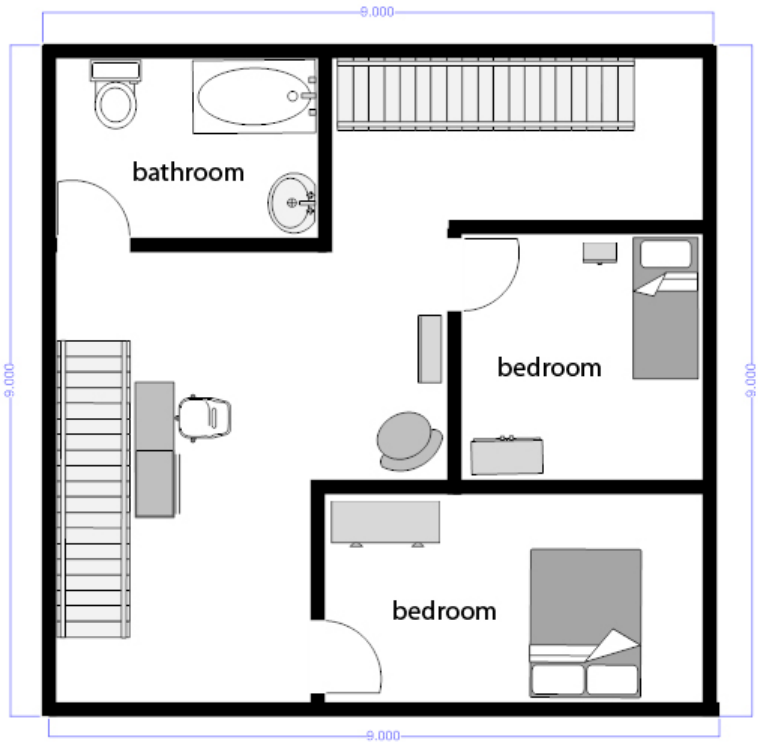
Access on the roof: yes

Number of inhabitants: 3

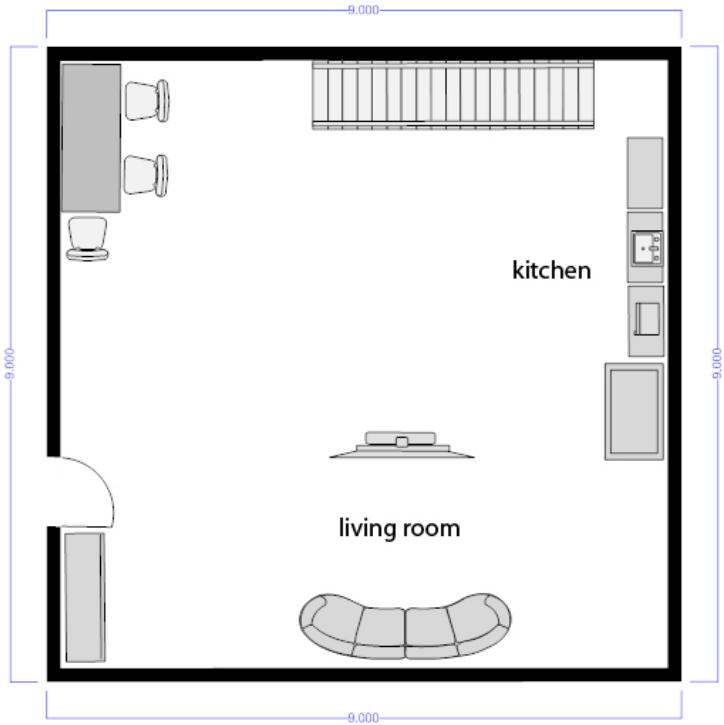
Area:

-ground: 81 m² (≈871.9 sq.ft.)

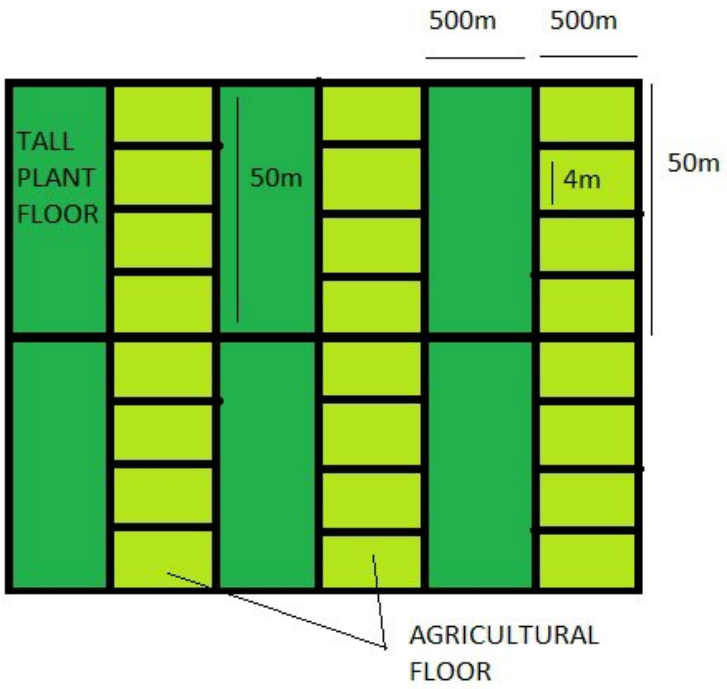
-first level: 81 m² (≈871.9 sq.ft.)

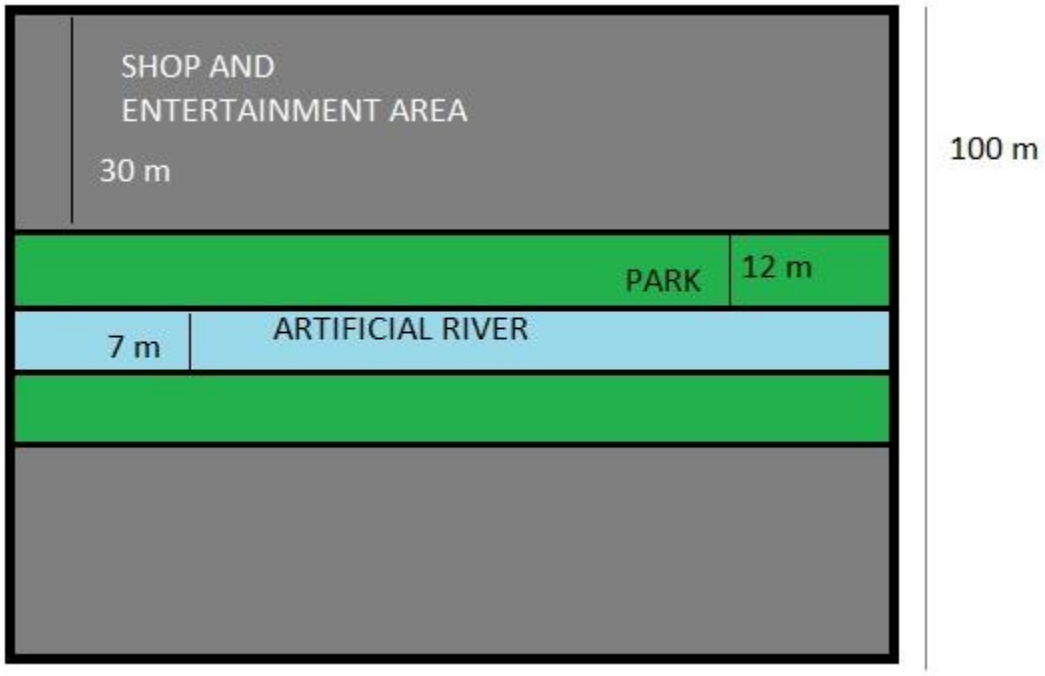


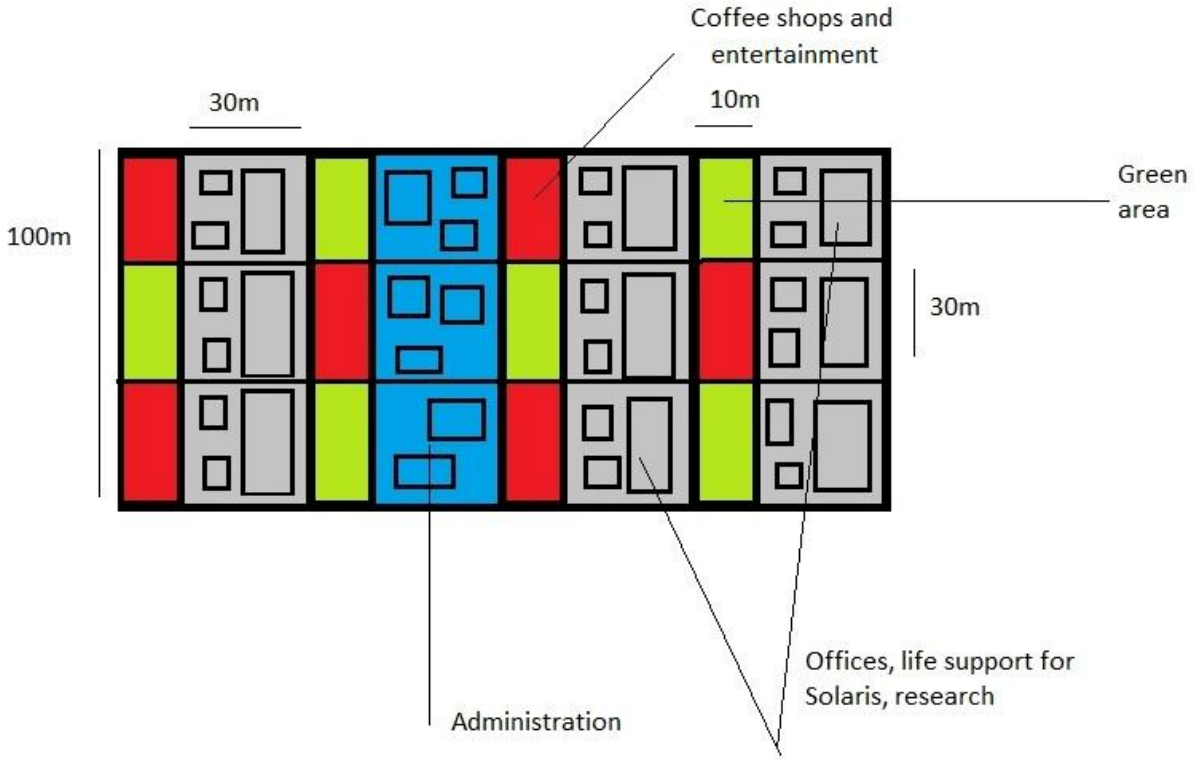
Ground

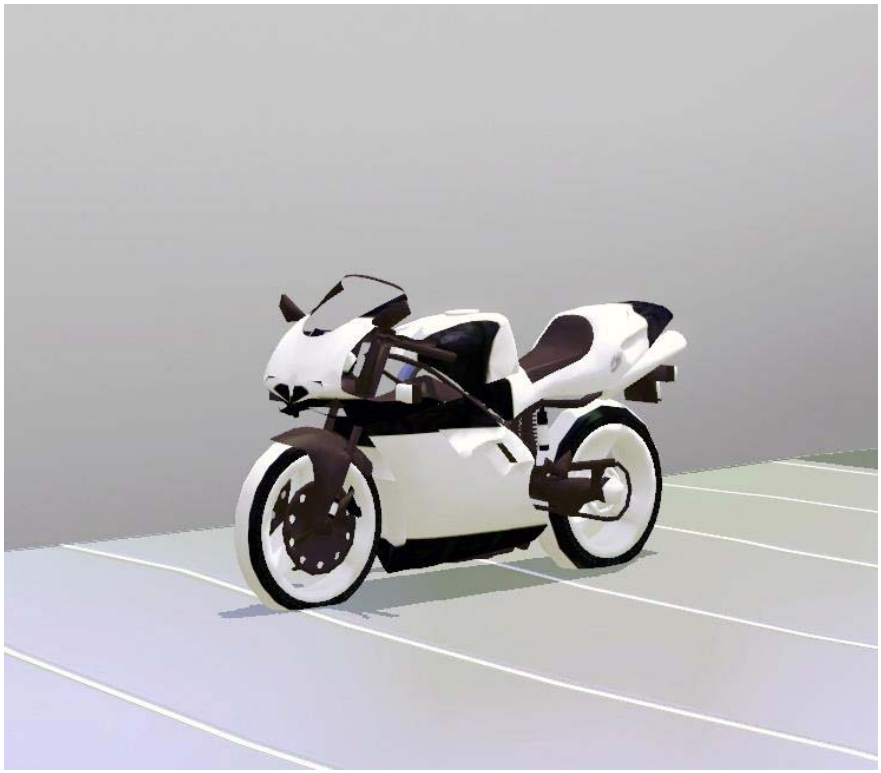


First level

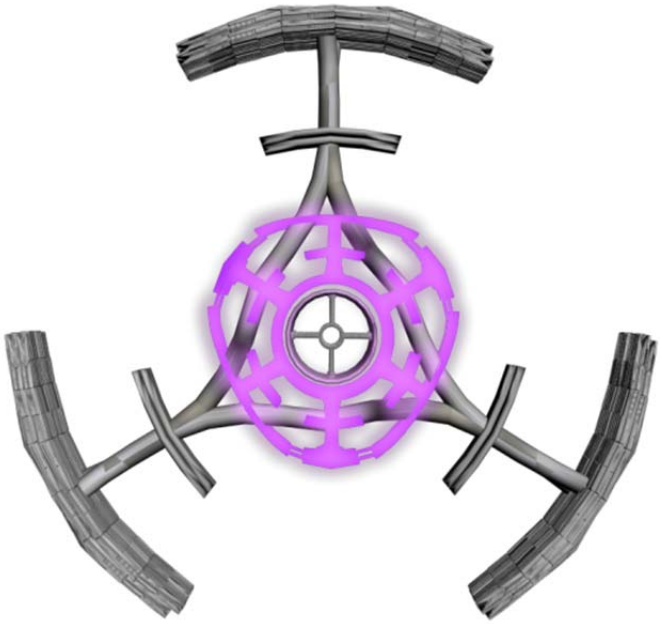

500m
500m
TALL
PLANT
FLOOR
50m
4m
50m
AGRICULTURAL
FLOOR


SHOP AND
ENTERTAINMENT AREA
30 m
100 m
PARK
12 m
7 m
ARTIFICIAL RIVER

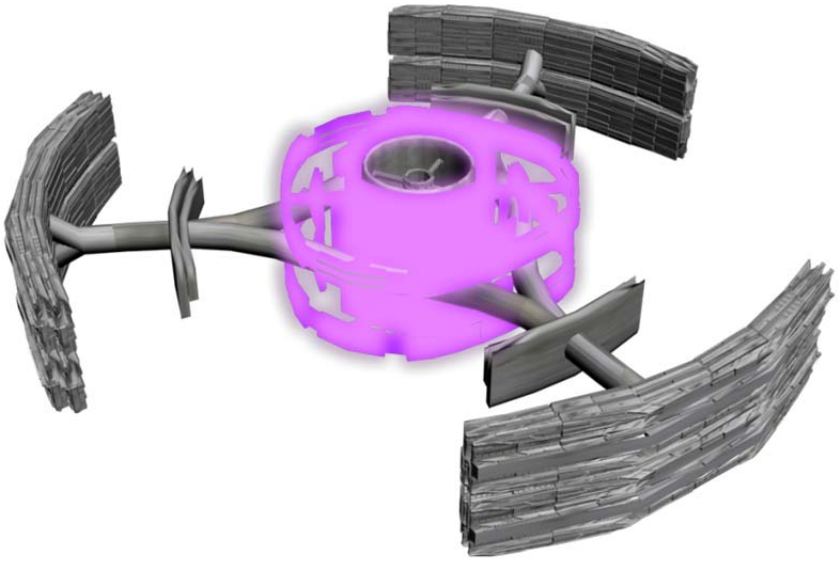

Coffee shops and entertainment
30m
10m
Green area
100m
30m
Offices, life support for Solaris, research
Administration



a. Rotating Segments

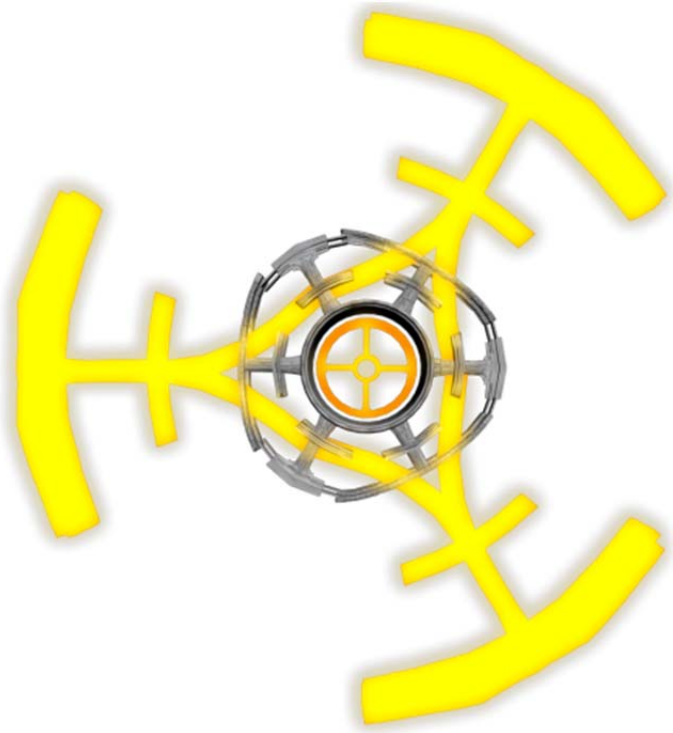


Rotating Segments Top View

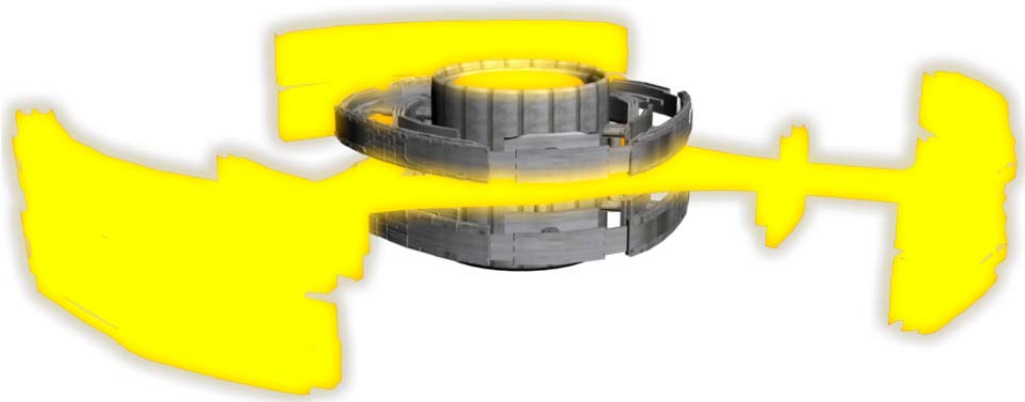


Rotating Segments Perspective View

A. NON-ROTATING SEGMENTS

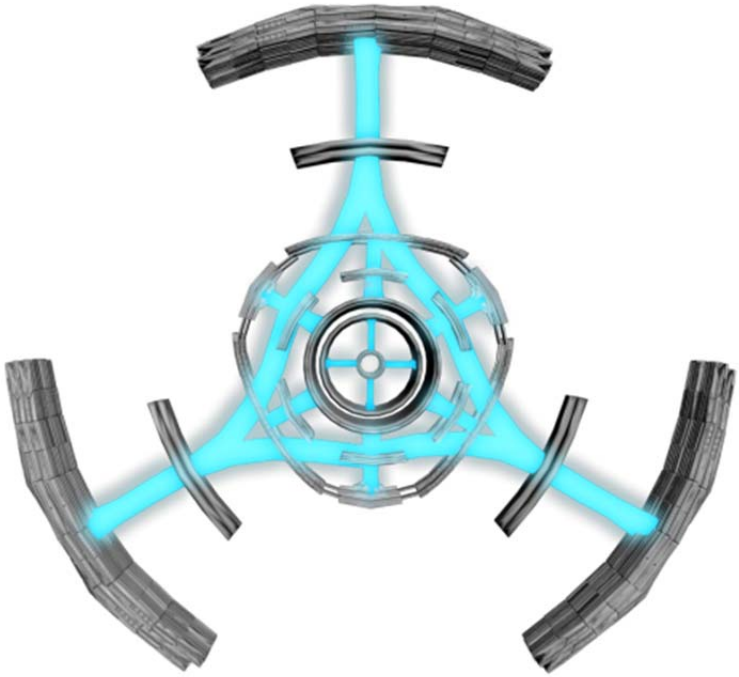


Non-rotating Segments Top View

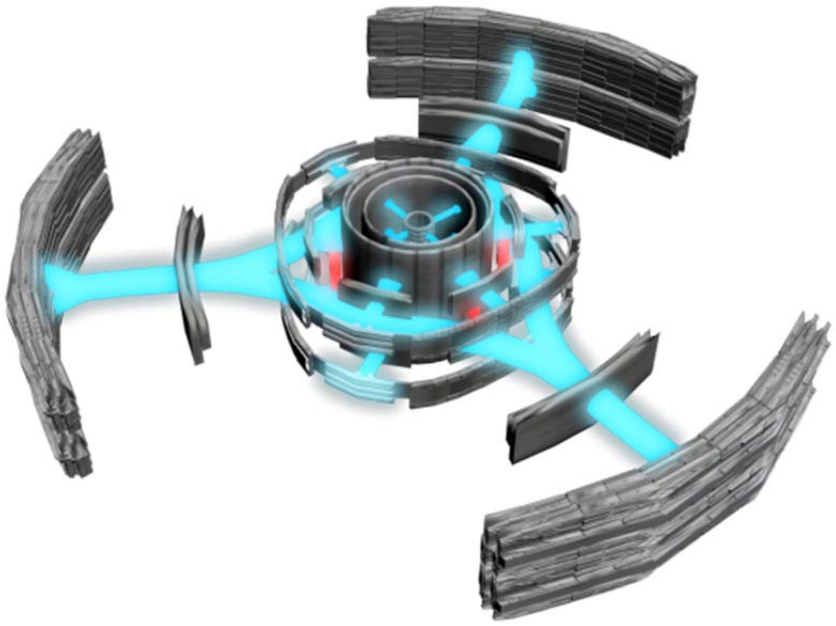


Non-rotating Segments Perspective View

B. STRUCTURAL SEGMENTS

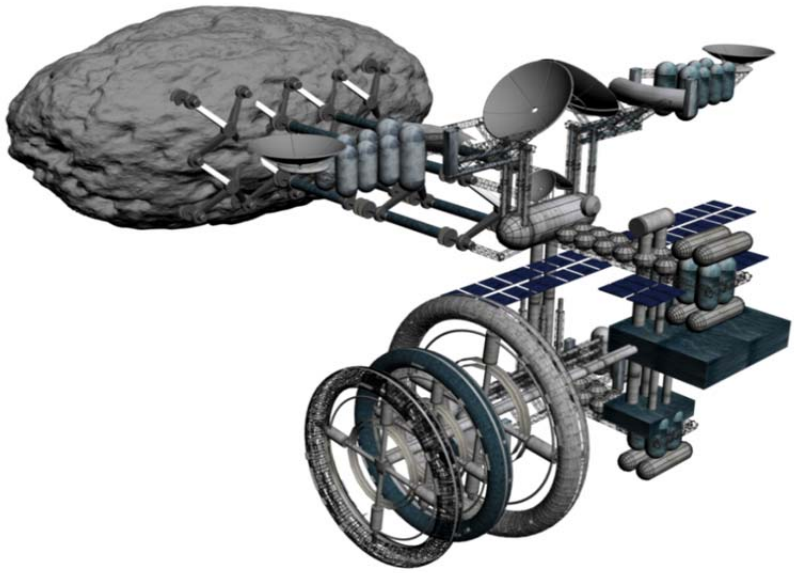


Structural Segments Top View



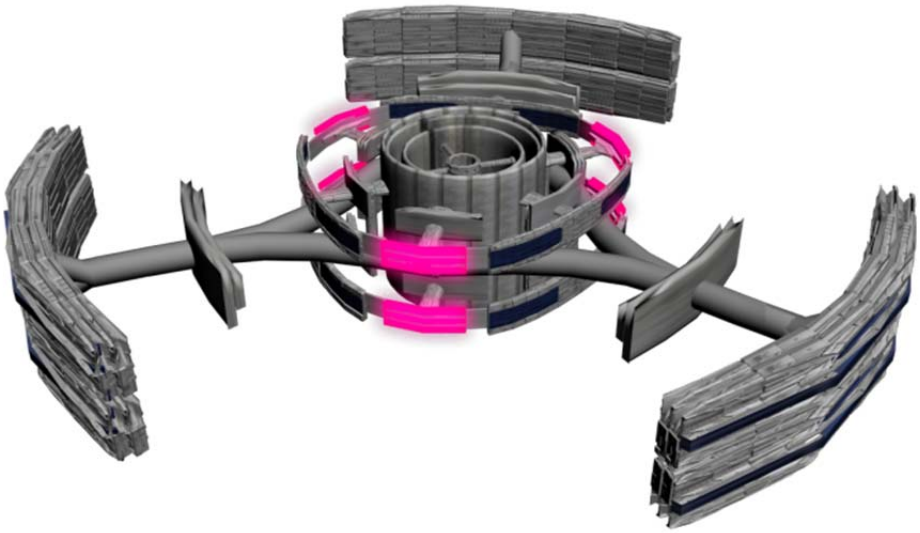
Structural Segments Perspective View

C. Mining Section



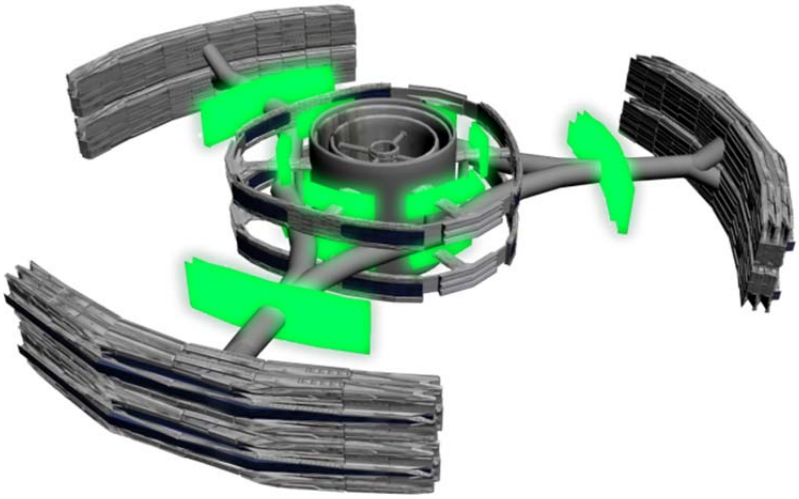
Mining Perspective View

D. INHABITED



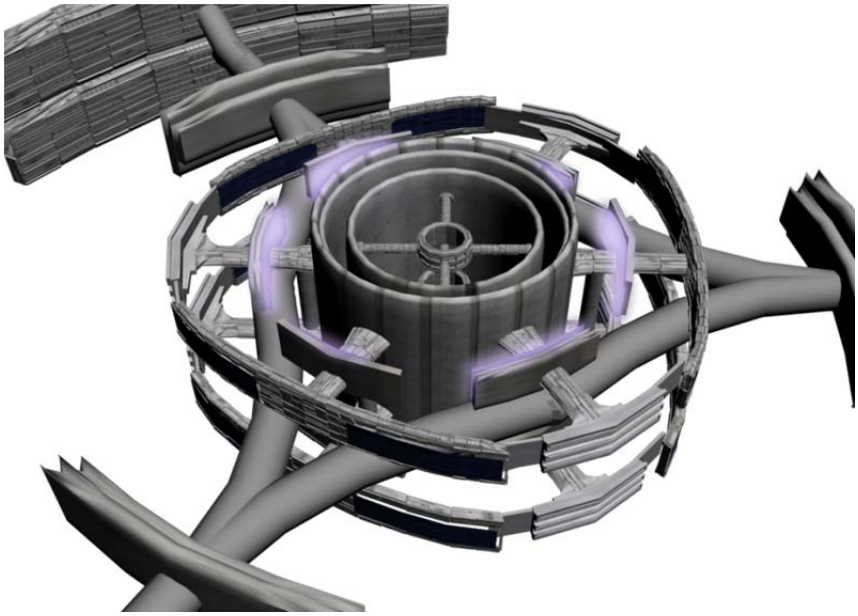
Inhabited Perspective View

E. AGRICULTURE

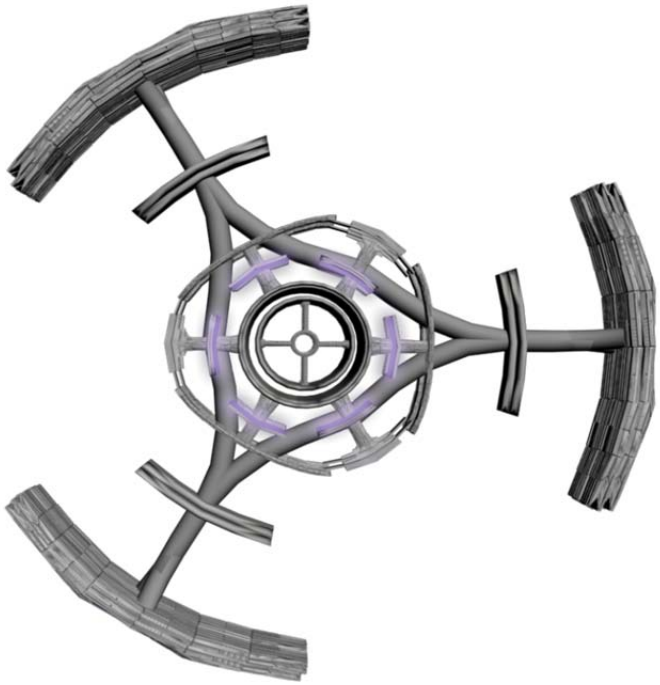


Agriculture Perspective View

F. STORAGE

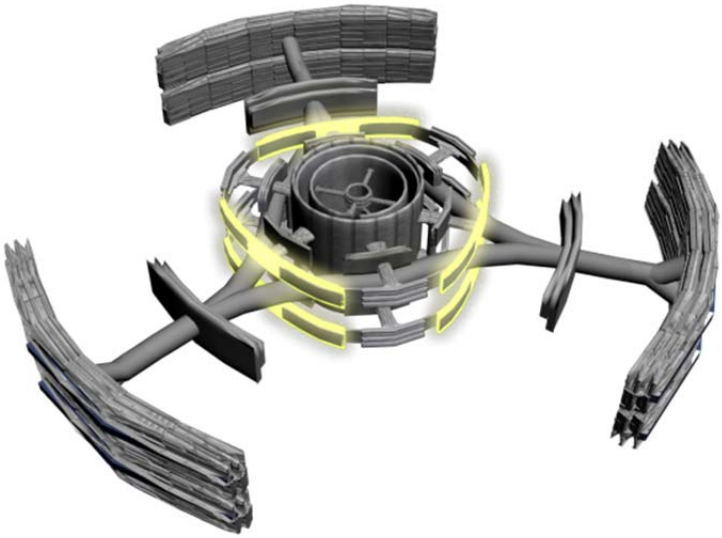


Storage Perspective View



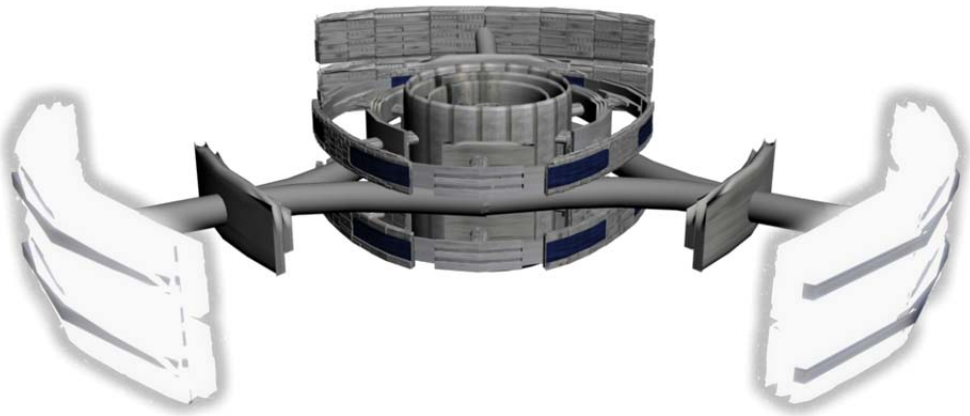
Storage Top View

G. ENTERTAINMENT

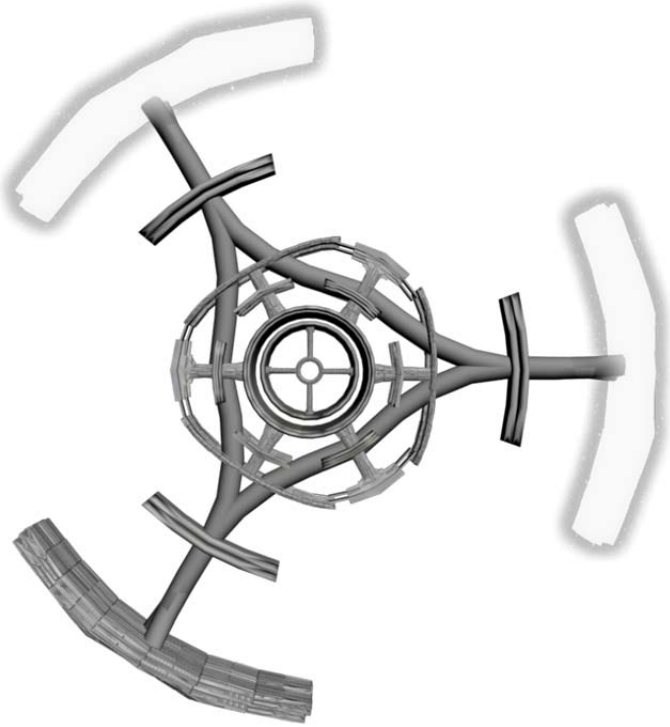


Entertainment Perspective View

H. MINING

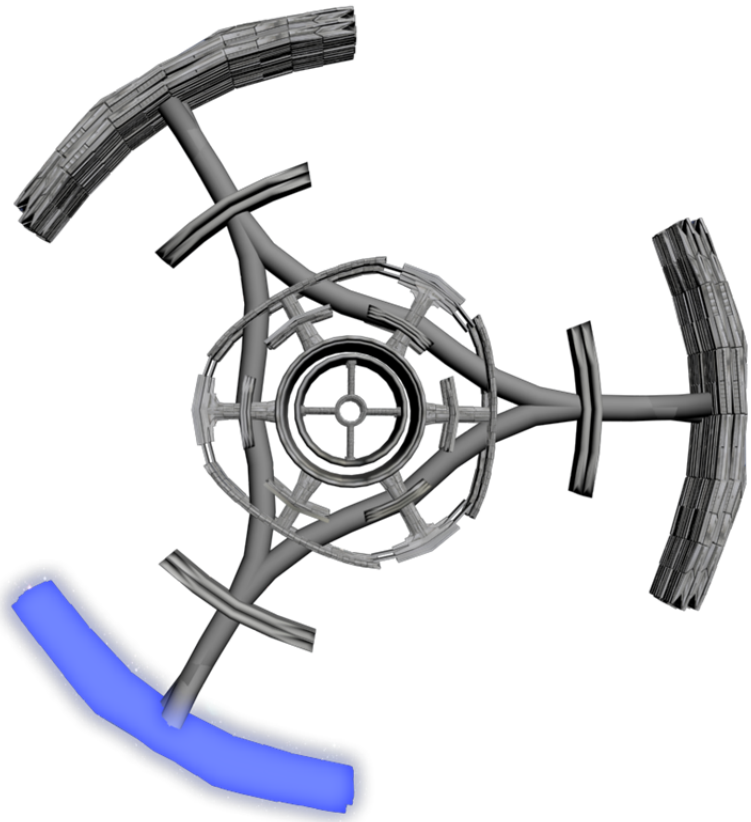


Mining Side View

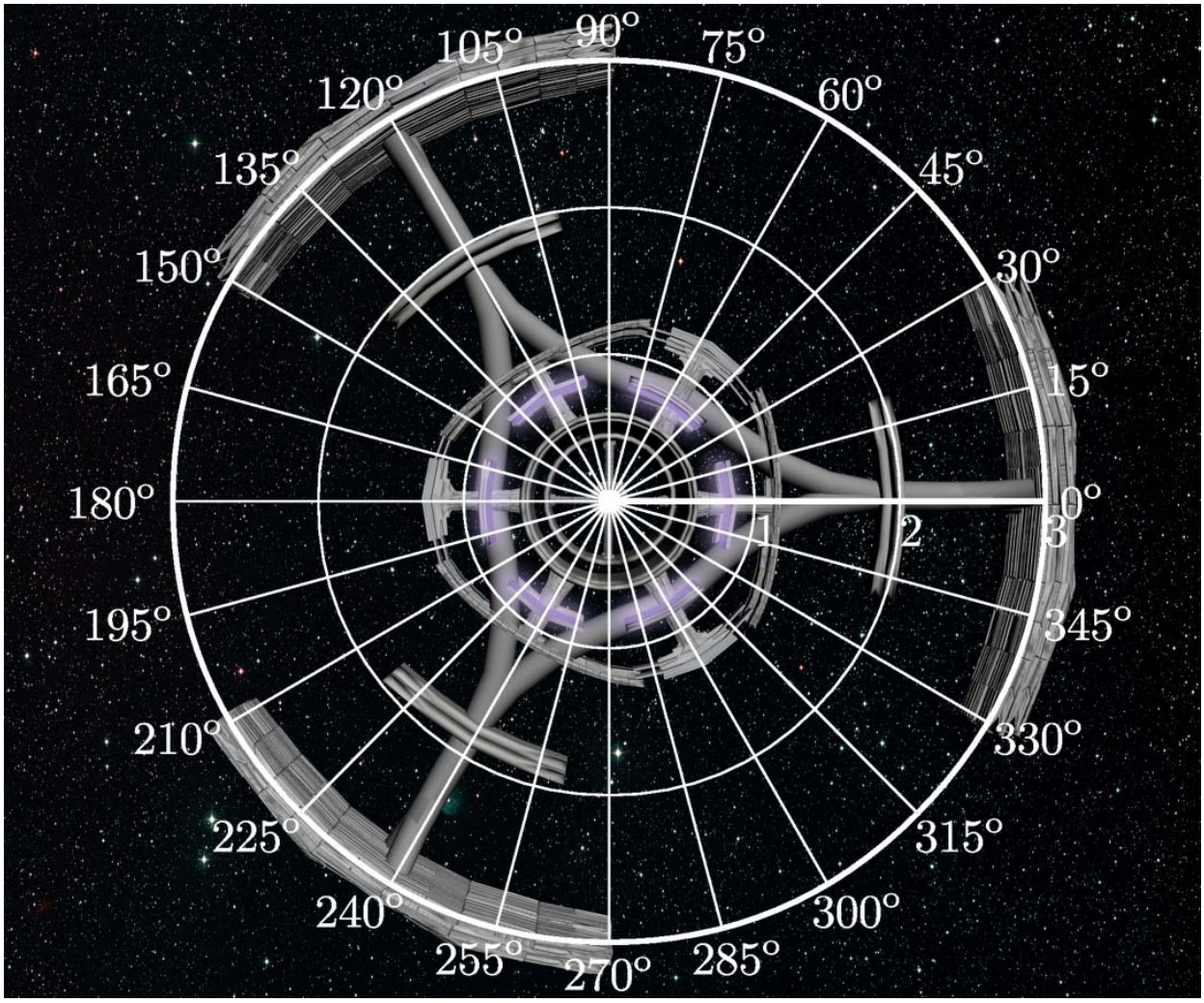


Mining Top View

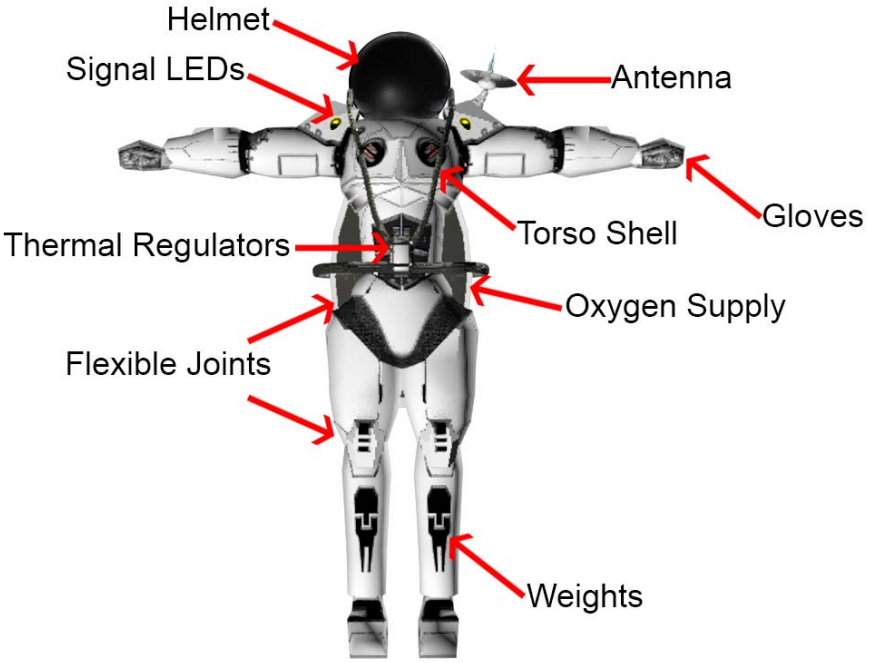
I. NUCLEAR



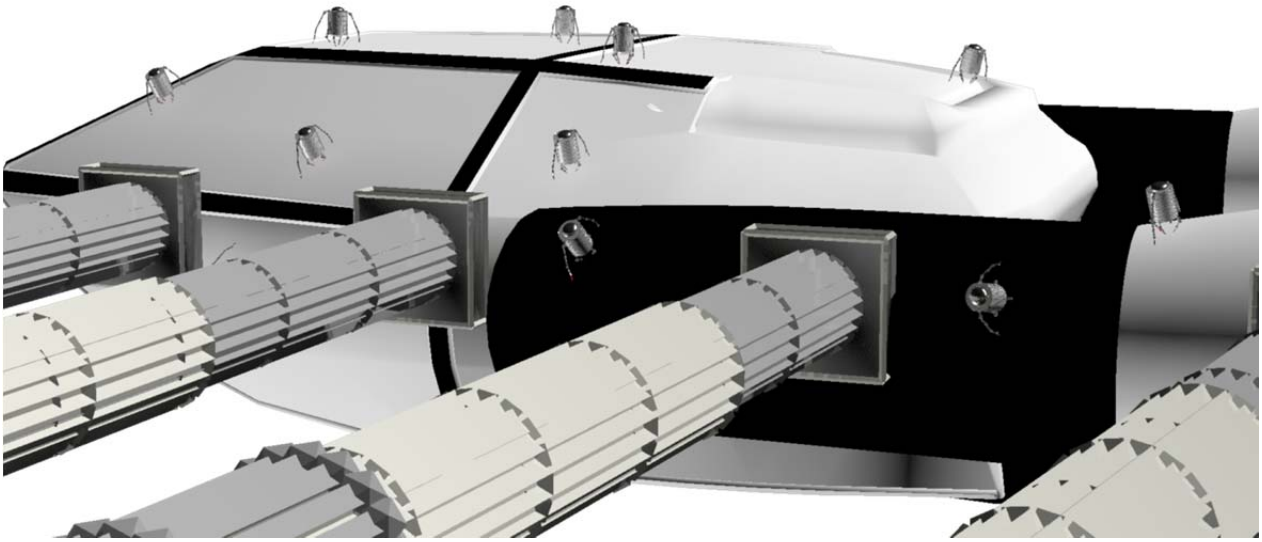
Nuclear Top View



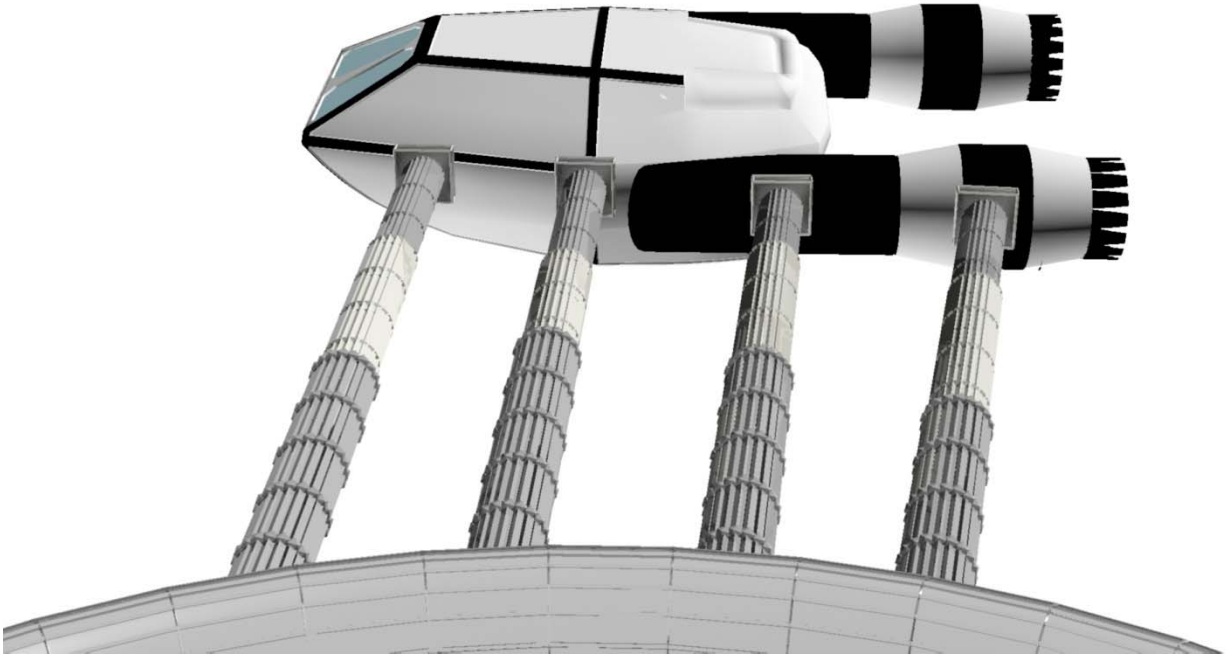
Radial coordinates



Body suit



Robots repairing ship



Docking module

Robots building a house

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