Space Settlement

Location

There are a number of viable location options to place the settlement in outer space. The location must have balanced gravitational field forces between two objects. For this settlement, locations where the Earth and Moon's gravitational field strengths are equal have been looked at. The ideal location for the settlement would be a suitable distance between the Earth and the Moon so that trips could be made to both with relative ease. To suit these constraints, the Earth-Lunar Libration point L1 was chosen to hold the settlement. At this point, the Earth and moons gravitational field strength is exactly equal, so the settlement can remain in a stable position. The Libration point L1 is a geostationary point – meaning that the settlement will rotate around the moon at the same rate that the moon rotates round the Earth, and therefore remain at the same point relative to the Earth [2]. This location also allows fast communication between the Earth and Moon and also enables travel to the moon to obtain any supplies such as natural material or natural gas.

Constructing the whole structure in space could prove to be a challenging task, as it would require extremely skilled workers who are also trained astronauts to safely construct the settlement. However, having zero gravity means that large machinery is not needed and large objects can be manoeuvred around much easier. Living on the space settlement means that while living there, the residents are completely confined to be "indoors" 24/7, which could prove to be challenging for some people. Efforts have been made to make the settlement as "natural" as possible, however, there is unfortunately no way for the conditions to mirror conditions on Earth that humans are accustomed to, e.g. the changing climate, heavy rains or true fresh air.

Using the Libration point L1 rather than a location orbiting Earth means that there is no possibility of the settlement being damaged by space debris.

According to the European Space Agency, there are around 21000 pieces of space debris orbiting the Earth. These pieces of space debris are travelling at speeds of multiple kilometres per second around Earth, which could potentially cause millions of pounds worth of damage to the settlement if a collision occurred. These pieces of debris come from satellites and space stations situated around Earth's orbit and consist of screws, nails or generally anything that can be let loose from space structures. These pieces of space debris would be an extra worry if the settlement were situated within Earth's orbital path. However, using the Earth-Lunar L1 Libration point, the settlement will not come in contact with space debris – it is only meteor particles that the settlement will be exposed to. There is still a possibility of collision, but this possibility is drastically reduced using the Earth-Lunar L1 Libration point.

Structural Design

The shape of the settlement plays a major role in its functionality. The settlement will have circular outer walls so that its rotation will produce the centrifugal force, imitating the gravitational force that is felt on the Earth's surface. The chosen shape was a thin-walled cylindrical vessel. It was decided that the flat walls of this shape would allow for the solar panels to fit together on the side, rather than having a spherical or ring shaped which has constant curvature on the outside. The dimensions of the settlement are shown below:

	Dimension (m)
Outer Diameter	**1600**
Inner Diameter	**1360**
Height	**200**

Table 1 – Outer Dimensions of the Settlement

These dimensions were estimated to be able to give adequate living space for 10,000 people, as well as enough space for facilities to entertain the residents and encourage them to stay long term.

The aim was to have 1g of gravitational field strength on the outer walls of the settlement. The exact rotational speed to produce 1g was calculated by the following:

Where radius, R = 1600m and the centrifugal acceleration, . The recommended speed to produce this artificial gravity is:

This will be the centrifugal force on the outer walls of the settlement. However, the residents will live on Floor 2, which is closer to the centre of the ring. This means that the artificial gravitational force will be slightly less at a value of 9.3 m/s^2 at ground level on Floor 2. This is only a change of 0.051g from the gravitational field strength on the surface of the Earth. To put it into context, a lift going up for down would produce a change of 0.1g. This means that there should be no problem for the bodies of the residents to adjust to the new gravitational field strength.

The external ring would be a series of layers that serve multiple purposes for the safety of the settlement. There will be an inner skeleton that is made from steel that is the outline of the structure. This is there to provide a solid structure with high stress resistance so that the settlement holds shape and has no risk of collapsing. The outer skeleton will be a truss structure; therefore the material will require a very large tensile strength. The material used will be Carbon Steel

Alloy, which has a Tensile Strength of 540MPa. The Carbon Steel Alloy has Thermal Conductivity of 51.9 W/mK [8], which is higher than other forms of steel, however, less importance was placed on this property for the skeleton structure, as it will not be exposed to high temperatures.

Covering the skeleton will be a layer of Titanium Aluminide. The properties of Titanium Aluminium Alloy 6% - 4% are shown below [3].

Table 2 – Titanium – Aluminium Alloy Properties

Material	Yield Strength (MPa)	Density (kg/m^3)	Thermal Conductivity (W/mK)	Coefficient of thermal expansion (K^-1)
Ti 6% - Al 4%	910	4420	7.2	9.2e-6

This Ti 6% - Al 4% alloy was chosen due to its ability to withstand great temperatures. It has a low thermal conductivity and low coefficient of thermal expansion compared to other compositions, e.g. Ti 3% - Al 1.5%. . This means that the material is resistive to heat conduction and it will not expand a large amount when it is exposed to the heat of the sun. The strength to weight ratio for Titanium Alloys are also exceptional, which is advantageous for shipping the settlement materials into outer space. The Titanium Alloy will also serve as a sufficient radiation protection shield as it is proven to be so on numerous space missions, such as the Juno Spacecraft, which is set to orbit around the planet Jupiter [13].

<u>Meteor Protection</u>

The next layer of material will be a meteor blocking system that protects the settlement from rogue space debris and small meteors. One of the most effective ways to protect a space ship from meteorite particles is to use a Whipple Shield. There are different types of Whipple Shield that provide varying levels of protection. For this space settlement, the whole outer ring will be made from a Nextel/Kevlar multi-shock Whipple Shield. The total thickness of the multiple walls of Nextel/Kevlar protection on the settlement will be around 12cm thick. This has previously been used to protect the CONTOUR (comet nucleus tour) spacecraft from meteor particles [4]. The multiple layers of Nextel block the meteor particles so that the meteor cannot reach the inner walls of the settlement. The purpose of the Flexible Multi-Shock Whipple Shield is to fragment the meteor particles that collide with the system. This type of shield was used in the ISS and reduced the chance of damage to the structure by a factor of 3 [4]. During this mission, optimisation calculations were made to determine the likeliness of collision with the different areas of the structure, which meant that money could be saved by reducing material costs.

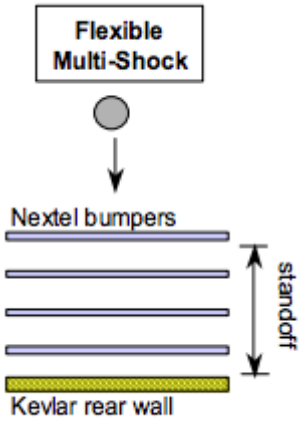


Figure 1 – Multi-Shock Whipple Shield Layers

There are three ways that Christiansen [4] looked at improving on the shielding system that he presented in his paper. 1) To continue to improve on the Kevlar/Nextel multi-walled system, 2) To look at health monitoring of the multi

shock systems, that will allow for Maintenance Engineers on the settlement to determine the structural integrity of the outer shell and 3) To research new materials as a substitute for the meteor protection system.

The final layer on the outer wall of the settlement is the solar panels. The whole outer wall of the settlement will be tiled with these solar panels to ensure maximum energy is extracted from the sun. These will be covered with pseudomorphic glass (PMG), which was developed by AFRL to provide radiation and mechanical protection to the solar panels. The PMG cover glass is composed of "ceria doped borosilicate or fused silica beads incorporated into a variety of polymer matrices" [5]. The PMG is cost effective and easily manufactured, while protecting the solar panels from radiation and small collisions. Obviously, it is not expected for the cover glass to protect the solar panels from high-speed meteor particles, as they can travel at speeds of multiple kilometres per second. In the case of solar panel damage, there will be Maintenance Engineers who will be adequately trained to replace solar panels.

Electricity Generation

The settlement will use solar energy to generate electricity. As stated, the solar panels will cover the outer wall of the settlement to catch as much solar energy as possible through rotation. The solar panels will be Monocrystalline Solar Cells, chosen for their high efficiency and heat tolerance [6].

As the settlement will not receive constant sunlight, the energy that the solar panels use will be stored whilst the settlement is in the Sun's path. To store the energy, high-speed flywheels will be used to convert the electrical energy into kinetic energy to spin the flywheel. Another method of storing energy would be flow batteries.

The flywheel is a possible energy storing method because it is compact and does not require much space and it can respond instantly to energy changing needs, which means that at any instance the settlement requires a surplus of energy, the flywheel can be used to supply it.
As soon as energy is needed from the flywheel, leads can be attached to the flywheel and the kinetic energy is converted into electrical energy to power the settlement. As the energy is released from the flywheel, it slows down due to energy loss. On the settlement there will be multiple flywheels that will power the settlement over the lunar nights.

Flow batteries can store a large amount of energy by storing electrical energy in electrically charged liquid as a result of an electrochemical reaction. Large amounts of energy can be released quickly, however, a large amount of space is needed for this method of storage [7].

Atmosphere

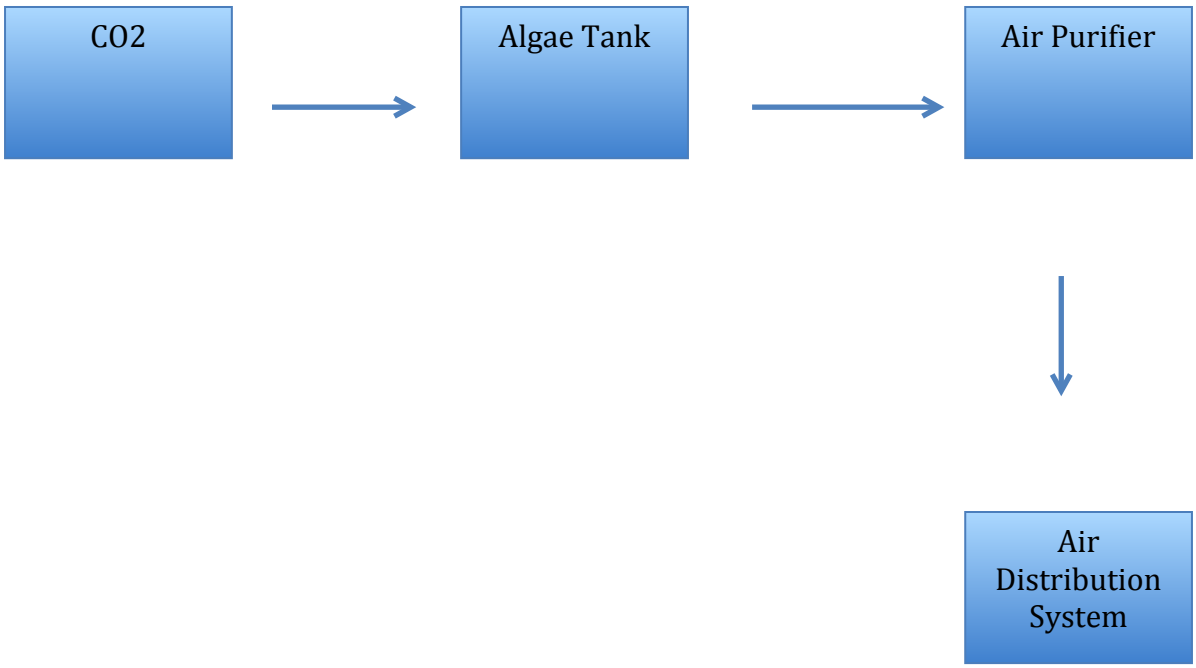
To create a comfortable living environment for the residents to live in with clean, fresh air it is essential that the correct oxygen reproduction systems will be put in place. It would be far too costly to constantly be importing supplies from Earth to space so it is important to create a system that is self sufficient and reliable to supply oxygen to the settlement. The Earth has its own natural oxygen recycling system called photosynthesis. This occurs when plants take in the carbon dioxide which humans and animals produce, process it then produce oxygen into the atmosphere again. The growing of the crops on the settlement will produce large amounts of oxygen, but it is uncertain that it will produce the required amount to sustain life on the settlement, so oxygen reproduction systems are essential.

Algae are the most efficient type of plant at converting carbon dioxide into oxygen and could be a suitable solution for the settlement. Currently on the ISS, oxygen is created from electrolysis, which splits water molecules into Oxygen

and Hydrogen. Here the oxygen can be retracted and re-introduced into the air and the Hydrogen used can be combined with excess carbon dioxide to reproduce the water that was used to create the oxygen [1].

It is thought that the electrolysis is a simpler, and less labour intensive form of oxygen production, however, the algae tanks are still in early stages of testing [1] so it is likely that in the future, the algae system could be a more efficient system.

Algae is submersed in water tanks while the un-oxygenised air is pumped into each tank. The algae will then react with the un-oxygenised air and produce oxygenised air as a result of photosynthesis. The air can then be obtained and put through an air purifier to make sure the air is fit to breathe and it has no distinct smell. After this, the air can be distributed around the settlement using the air conditioning system. Below shows the process of producing oxygen through algae tanks, then cleaning the air to pump into the atmosphere.



Daily Weather

The daily “outdoor” weather will be relatively stable. The air distribution system will ensure the air is between 23°C and 26°C during the day and between 18°C and 22°C at night. The weather will fluctuate slightly from day to day to mimic weather on Earth.

Since no sunlight will be let into the settlement, there will need to be a solution to best mimic life on Earth for the settlers. Humans are designed to rely on the light from the sky to support their sleep cycles, so a steady reliable sky above is essential. The sky will be made from hundreds of LED Skylights. These skylights will be Ultra High Definition quality to give the best picture of the sky as seen from Earth. This artificial sky can show clear skies but also show clouds during the day and present constellations at night so allow for stargazing without going to the observatory. The artificial sky will include Sun lamps to represent the shining light of the sun as well as UV lamps to supply humans with vitamin D.

Interior design

The interior design of the structure will have enough space inside to allow 10,000 inhabitants a comfortable and enjoyable life in the settlement. This means reproducing a city-like settlement that can meet all the needs of the settlers to encourage them to stay long-term. The settlement will have 2 floors:
Floor 1 will be the “underground level” which will hold the subway system and the food production facilities.
Floor 2 is where the residents will live their daily lives. It will have all of the accommodation, as well as a wide range of daily activities for the residents to enjoy an active exciting life in space. There will also be Community and Health facilities on Floor 2 to keep

Floor 1

Transport

Efficient transport for the whole settlement is an integral part of the settlement. Residents need to feel like they have the facilities to move around freely and quickly to other parts of the settlement. Efficiency is key – to get as many people travelling in as little a time as possible. The primary mode of transport for the residents will be an underground subway system. There will be three different subway vehicles travelling in both directions, each with four carriages. There will be an inner and outer circle subway so that residents can travel in each direction for convenience. Each vehicle can carry around 300 people at a time, and there will be three vehicles on each side of the track at all times, meaning that residents will not be waiting for more than 10 minutes for a subway. The stops will be made to align with the important destinations in the settlement, for example, the hospital, multiple stops at the residential area, and at the popular areas of the central module. The vehicles will have a max speed of 60 mph, however, it will not reach this speed due to the small distance in between stops.

The possibility of high-speed singular pods was considered, however, it was thought that this would be inefficient at mass transportation and therefore was disregarded.

Walking is also an option for the residents as there will be a wide road running down the centre of Floor 2 of the settlement. There will be no cars running through this road, except in emergency, where a police car or ambulance would need to move around the settlement at high speed. In this case, there will be warning lights all along the road for people to move aside as there will be a high-speed vehicle coming. There will also be spacious pavements on each side of the road, which residents can use. Similarly, if any vehicles need to transport heavy loads, the same roads will be used. However, it is assumed that once initial construction is finished, there will be little need for transport of heavy goods around the settlement.

The food production

Floor 2

The Second floor will be separated into 3 modules: the Residential Module (1888m), the Central Module (1888m), and the Health and Maintenance module (1250m). Residential and Central modules will be slightly longer in length than the Health and Maintenance module due to a greater requirement of space to fit the needs of the people.

Residential Module

The Residential module will be created to be a suburb for the 6000 long-term residents to stay in. This module will contain all of the necessary needs for the residents to live their daily lives, with the option to go into the vibrant Central Module. The distance of the module will be 1900m long

Housing Sector

The main focus of this module is the accommodation. There will be a section of 1km that is dedicated to the housing for 6000 full-time residents. This housing sector will consist of both two-bedroom and one-bedroom apartments that will be suitable for 4 and 2 guests, respectively. This means that both families and couples can settle here long term. Having apartment blocks means that the full height of the ceilings of the settlement can be used for living space.

*****Blueprints of Homes****

Residential activities

The residents will have access to a range of local shops for their daily needs. This will include local grocery stores, DIY stores, postal service, local eateries etc. This

module will contain a park linking the Residential and Central module with artificial grass so that the residents can come and relax and socialise in their free time. The LCD screens for the roofs will provide an excellent setting to sit and stargaze in the dark with loved ones. This is something that a ceiling would not give you due to light pollution; however, the LCD screens would produce magnificent consolations. The park will also have a play area for children.

For health reasons it is extremely important to have areas where the residents can exercise. The park is one area for people to walk, run or play but many people need an assigned area for exercise with weights, treadmills, cross-trainers, rowing machines etc. This gym will have all the equipment mentioned and be a suitably dimensioned area for the many long-term residents. An outdoor running track will be installed for “track and field” events. There will also be regular sports events that residents of all ages can take part in, which will serve for exercise and entertainment. For both mental and physical health purposes it is recommended that most residents take part in around 20-30 minutes moderate exercise per day. This could be either walking, running or lifting weights.

A school that will hold around 500 students will be constructed in the hope that this encourages families to live on the settlement. It is important to do all that is possible to support family life here, in the hope that the clientele is as diverse as possible.

There will be a local observatory in this module, which will use many Ultra HD cameras placed around the outside of the settlement to produce an almost real life picture of space outside the settlement. Settlers will be able to see the Earth as they orbit round it and great views of the moon. It is expected that this will always be a jaw dropping experience for the residents.

As a place for political or community discussion, there will be a community hall in the local residential area. It will serve as a place where local representatives can inform the local residents of any plans or changes made that may affect their

lives in the settlement. The community hall will be able to hold around 2000-1000 people, and talks will be televised to residents at home. There will also be weekly talks from individuals on interesting, informative topics of any sort – ranging from science to history and anything in between. Scientists from the research labs can also come and present their findings to an interested audience. There will be areas left free for future expansion for more housing and other construction can take place in future years.

Central Module

The Central module is focused around the short-term residents who decide to visit the settlement for a holiday or to visit family who live on the settlement. This will have a more city-like, vibrant atmosphere than the Residential module and it will hopefully be the most profitable module. The holidaymakers will stay in a hotel with both luxury and budget rooms so this can attract people of all classes. The hotel will hold a maximum of 600 short-term residents and contain restaurants and bars, a swimming pool and spa area, and gym and sports facilities for the guests.

The short-term residents will use the large park that will link the Central and Residential modules. There will be a shopping mall, which will include branded fashion shops, space merchandise and equipment and some indoor food outlets. There will be a large open square surrounded by restaurants, bars and cafes. A Cinema, bowling alley and casino will be available to the residents as well. The long-term residents are also encouraged to treat this module as their city centre and travel in for days or evenings out.

Health and Maintenance Module

The Health and Maintenance module is the section of the settlement that helps it function. This section will be much shorter in length than the Residential and

Central Modules. It will contain the control centre and the medical centre of the settlement.

The hospital and doctor's office can hold around 200 patients. There will be doctor's working within the hospital 24/7 of many different specialities to ensure that the settlers will be cared for no matter what their condition is. The hospital will include in-patient wards where patients can stay if they are receiving treatment or require an operation. There will also be a doctor's office, which will deal with minor patient treatments that only require simple medication or medical advice.

The control centre will be the hub of all the electrical and functionality systems of the settlement. This section will include:

- The equipment to measure the amount of electricity generated by solar panels.
- Air distribution analysis equipment, which will test the air being pumped into the atmosphere for any impurities.
- Electricity storage. The chosen method of electricity storage (flywheel or flow batteries) will stay in the control centre. Whenever there is an energy shortage, the employees of the control centre can switch to the back up electricity generator to power the settlement.
- Laboratories that will be used for repairing equipment, such as solar panels, drones or robots.
- COMMUNICATION CENTRE *********

Within the Health and Maintenance Module, there will be facilities that will allow for research to be conducted that otherwise could not be conducted on Earth. Research laboratories within the settlement will provide an excellent opportunity to study Lunar gas and materials and meteor particles. Since the settlement will be within a reachable distance from the moon, it will be much easier to obtain samples of gas and materials from the moon to study in the state

of the art laboratories. Since most meteor particles also burn up in the Earth's atmosphere, it is not possible to study their properties on Earth, however since the settlement is outwith the Earth's atmosphere it would then be possible to study these particles. This would mean that technology would have to be created to catch the meteor particles, or if any particles collide with the settlement, they will get trapped within the Whipple Shield, which means they could be extracted and studied.

Airlock System

The purpose of the airlock system is to provide a safe medium between inner settlement and outer space. The airlock means that there will be no significant loss of pressurised air to outer space when Astronauts are leaving the settlement. There will be one airlock system for each module, which will be placed on the outer wall of the settlement. Each airlock will have the capacity to hold three spacesuits and their equipment. Most likely, it will be Maintenance or Electrical Engineers that will be trained to carry out regular checks on the health of the structure and repair any damages on the settlement, such as structural damage, or electrical repairs on the solar panels.

The airlock system works as a room that separates the inner settlement and outer space. The airlock has two doors, which cannot be opened simultaneously. For the Astronauts to get ready the airlock is pressurised and the first door is opened which connects the inner settlement to the airlock. The Astronauts are helped into their spacesuits by other crewmembers. When the Astronauts are ready to leave the settlement, the crewmembers leave and the first door is shut. The airlock is then depressurised and the door to outer space is then opened, and the Astronauts can enter into space.

Fire Safety

In the unlikely but dangerous scenario of a fire, the settlement will provide safe and logical solutions to keep residents safe and stop the fire from spreading. Firstly, indoors, there will be smoke sensors in each room to detect smoke. The sensors will be accompanied by sprinklers that will spray liquid nitrogen to smother the fire. Each household will be also accompanied by a fire blanket and its own fire extinguisher, so that residents can reach areas that the sprinklers may not concentrate on. Buildings will be designed with heavy fire resistant doors so that the fire does not spread easily. The settlement will also have on duty fire service that will be on call 24/7 to ensure that in the case of a dangerous fire, trained individuals can ensure the fire is safely put out without risking many lives. The fire service will also provide useful advice on fire prevention and train residents on the procedure for residents in the event of a fire.

Outdoor fires pose a greater threat to the settlement due to their risk of spreading. The outdoor sprinklers that will be imposed may not have as great an effect on the fire due to their height above the ground and the large spaces between sprinklers. Large fire resistant shutters will be introduced at regular intervals through the settlement that will close to ensure the fire is isolated and prevent fire spreading.

In the event of an outdoor fire that is deemed dangerous by the fire service, the people in the module will be evacuated to the safe rooms provided, which have thin body suits with back up oxygen inside. The shutters will close in the module, isolating the fire, and the oxygen supply will be cut from the module to ensure the fire is not fuelled. In the case that the fire is that bad that some of the settlement is uninhabitable, there will be emergency shuttles that will be used to take residents safely back to Earth.

Air Contamination

There will be sensors in the air distribution system that can detect if there are any harmful chemicals in the air and shut down the primary air distribution system to stop the air from being emitted into the settlement. As a result, the back-up air distribution system will be produce air for the settlement. This back-up air system will come from the farming module, where some of the oxygen produced will be stored for emergency uses.

In the case of harmful gases being emitted from inside the settlement, a sensory system on the settlement roof can sound an alarm and safety procedures can take place. People will be evacuated from the area, and the same airtight shutters used for the fire safety procedure will be used to stop the gas from spreading.

In the event of a power cut, the excess stored electricity will be used to provide power through a separate electrical grid to provide temporary power to the station. The Maintenance Engineers will be on hand to fix the problems that occur.

In the event of low power availability, the non-essential systems will be taken offline to save the power output, while electrical power is generated back to regular levels.

Technological Services

The settlement will make use of a network of self-driving drones that will be primarily used for deliveries around the settlement. The cargo will include stock for shops, food deliveries and there will be a postal service that delivers letters and packages to checkpoints for residents to pick up. The drones will have a maximum payload of around 50kg and there will be a fleet of around 10 of these to manoeuvre around the settlement.

The delivery drones will have a GPS system connected with a satellite near the settlement and contain a wide range of sensors. This would mean that only the

coordinates of the destination would have to be input into the drone for it to fly. The sensors would ensure that it is flying at a safe height relative to the ground and a safe distance away from other potential drones. The drones will provide a delivery service to residents on a regular basis. Each section of the Residential Sector will have an assigned delivery depot where residents can pick up deliveries from.

---TRANSPORT SHUTTLE BASES******

Costing

Phase 1: 2035 – 2055

The first phase of construction will include the outer structure of the settlement and the surrounding satellites. This will commence in around the year 2035, which will give enough time for meticulous planning and preparation for construction and will take around 20 years to complete.

Unit	Cost Per Unit ($)	Cost ($bn)	Rationale
Carbon Steel	$0.45 /kg	0.0142	Carbon Steel has a density of 7850 kg/m^3 and cost of $0.45/kg.
Titanium 6% - 4% Aluminium	$11.34/kg	1.11	Titanium has a density of 4420 kg/m^3 and cost of $11.34/kg. This will cover the whole outer surface of the settlement with a thickness of 1cm.
Nextel AF-10	$248/kg	37	Nextel has a density of 2800 kg/m^3 and a cost of $248/kg
Kevlar KM2	$1.5 /kg	0.016	Kevlar has a density of 1000 kg/m^3 and a cost of $1.5/kg
Solar	$769/m^2	0.087	1.96 m^2 per unit costing $769. Total

Panels			surface area needing covered is 2.222e6 m^2.
Satellites	$83 million	0.166	One main satellite and a back up satellite. This price is based on the SpaceX GPS3 satellite contract from 2016. [10]
Labour	$100,000 per annum per person.	40 per annum.	It is estimated that around 400,000 people in total will work on the settlement over the course of 20 years of construction. This is based on the similar figure that it took to execute the Apollo 11 mission [14]. All 400,000 people will not be working on it for the 20 year duration, so a yearly estimate will be suffice.
Total Cost		$78.39 bn	This total cost is the cost of construction and does not include transportation of materials. The labour cost will differ because there will be varying amounts of people working on the project from year to year.

Phase 2: 2065-2100

In phase 2 of the construction process, the inner features of the settlement will be designed and built in outer space. There are a lot of complex systems that have to be put into the settlement, so this phase will take a long time to complete. The settlement will be fully completed by the turn of the 22nd Century, however, it is thought that some residents may move in earlier whilst construction is still

on going, as long as the essential functions of the settlement are in place. The main features of the Phase 2 construction process are shown below:

Unit	Cost Per Unit ($)	Cost ($bn)	Rationale
Skylights	$39000	211	Cost to cover the Floor 2 ceiling with top of the range CE Pro skylights that show real time Ultra HD image of the sun, sky and stars. [12]
Hotel	$44.4 million	0.0444	This price is based on the “fixr” average price of construction to build a 250 room hotel [16].
Hospital	$1.5 million per bed	0.3	The average price of a bed in a hospital in America is $1.5 million. The hospital on the settlement has a capacity of 200 people. [17]
Shuttles	$10 billion	N/A	This price is based on SpaceX’s BFR, which will be used to transport people and cargo to and from the settlement. The settlement will sell off transportation rights to private companies such as SpaceX or Virgin Galactic.

Airlock systems	$164 million	0.492	This cost for 3 airlock systems is based on the Quest Airlock System, aboard the international space station. [11]
Drones	$10000	0.0002	This cost is an estimate of how much top of the range delivery drones will cost in the late 21st Century. There is not much data concerning delivery drone costs at this moment in time, however there is lots of design plans for future delivery drone prospects.
Labour	$100,000 per person per annum.	1.75	This is based on 500 people working on the settlement at all times for the 35-year schedule. The workers will earn an average of 100,000 dollars annually.
AI Robots			

Industrial Ventures

The settlement will need to be financially stable to continue to operate over a long period of time. In order to become financially stable, there must be planning of where consistent income will be coming from. Firstly, being among the first people in the history of mankind to live long term in space, this will come at a costly price. The rent for housing will be extremely expensive – the settlement will ask for prices that are similar to some of the most expensive areas on Earth per square metre. In return for the hefty price, the residents will experience a top of the range living conditions as well as the chance to experience something that only a handful of people have ever had the chance to experience. This is not to say that you have to be rich to live on the settlement. Many companies will provide sponsorships to employees to live aboard the settlement to complete research or scientific work. The hotel will also be more economically feasible for an experience in space. The hotel will not have to charge such a hefty price due to the concentration of people into a small area of land. This means people with a wider spectrum of income can visit space, to have the one in a lifetime experience or to visit loved ones on board.

Plots of land will be sold to businesses to use for their shops, gym and leisure facilities or any other business venture. The price will be determined by the size and location of their allotted land. There will also be a corporate tax on board the settlement that all businesses will have to pay 20% of their profits to the settlement.

Transportation between Earth and the settlement will be sold off to private companies such as SpaceX, Boeing or Virgin Galactic. The abundance in companies looking to invest in space exploration makes for healthy competition to keep standards high and prices low. Recently these companies, especially SpaceX have developed technology to reuse the rockets that get launched into space. This will save a huge amount of money, meaning the potential passengers will have to pay a great deal less to travel, making it more accessible for people to travel into space.

These companies will deal with passenger trips between Earth and the Settlement charging passengers to transport them to their destination. The settlement will also keep shuttles in ports at the settlement for emergency evacuation in case of fire or any other emergency occurrence where it is not safe for passengers to remain at the settlement. The chosen company will also transport cargo between the Earth and the settlement. This will include deliveries for shops, residents or even general necessities for the settlement, e.g. any food supply that may have run low. These space exploration companies will also pay corporate tax for their services to and from the settlement.
Selling the rights to the Earth – Settlement transportation is a huge expense that is taken off the books of the settlement. It is an enormous task to provide safe transportation for passengers and cargo, and it seems to make financial and logistical sense to offload this to private companies.

References

1) https://science.nasa.gov/science-news/science-at-nasa/2000/ast13nov_1
2) http://www.permanent.com/space-transportation-earth-moon-libration-points.html
3) https://www.azom.com/article.aspx?ArticleID=1341
4) https://ston.jsc.nasa.gov/collections/trs/_techrep/TP-2003-210788.pdf
5) https://techlinkcenter.org/technologies/flexible-solar-cell-cover-glass/
6) http://energyinformative.org/best-solar-panel-monocrystalline-polycrystalline-thin-film/
7) http://discovermagazine.com/2015/july-aug/26-power-stash
8) https://www.ezlok.com/carbon-steel-properties
9) https://www.alibaba.com/showroom/carbon-steel-price-per-kg.html
10) https://futurism.com/elon-musk-launching-a-satellite-with-spacex-is-300-million-cheaper/
11) https://en.wikipedia.org/wiki/Quest_Joint_Airlock
12) https://www.cepro.com/article/coelux_the_40000_fake_skylight_everyone_will_want
13) https://waverleybrownall.co.uk/blog/titanium-used-on-juno-spacecraft/
14) https://www.theguardian.com/science/2009/jul/02/apollo-11-back-up-team
15) https://www.esa.int/Our_Activities/Operations/Space_Debris/Space_debris_by_the_numbers
16) https://www.fixr.com/costs/build-hotel
17) https://www.quora.com/How-much-does-it-cost-to-build-a-hospital
18)
19)