ANASTASI 2032

FLETCHEL CONSTRUCTORS

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0 Introduction

What is an underwater base doing in a space settlement design competition?

Today, large-scale space habitation, and the opportunity to take advantage of the vast resources and possibilities of outer space, remains more in the realm of speculation than reality. We have experienced fifteen years of continuous space habitation and construction, with another seven years scheduled. Yet we have still not been able to take major steps towards commercial and industrial space development, which is usually the most-cited reason for establishing orbital colonies. This is mainly due to the prohibitively high cost, even today.

In this situation, we cannot easily afford the luxury of testing how such systems could eventually work in space. This leaves us looking for analogous situations. While some scientists have sought this in the mountains of Hawaii, this does not tell the full story. We are unable to properly fathom or test how a large-scale industrial and tourism operation, as it is expected will eventually exist on-orbit, on Earth. This led us to the idea of building an oceanic base.

The ocean is, in many ways, similar to free space. Large swathes of it remain unexplored. There are unrealised commercial opportunities. There are hostile yet exciting environments. Creating basic life support and pressure-containing structures are challenging. The ocean would thus provide for an excellent environment to simulate space settlement design at a much lower cost than constructing a space station like the ISS. The habitat could serve as a compulsory artificially simulated environment training visit for future astronauts going on space settlements.

Thus, we have decided to submit the design of a profitable underwater habitat to the Nasa Ames Competition **as a preliminary to space settlement infrastructure**. While it is not an orbital space settlement in itself, the rules mention that the project can relate to ‘activities leading up to a space settlement.’ This is why we came up with the concept of an underwater habitat, which will provide a 1g environment like a rotating orbital settlement while posing similar life support, transport and business related constraints. We hope that if nothing else, the project is an interesting read for the judges!

Acknowledgements:
We would first like to thank Mr. Al Globus, for organizing this contest every year promoting the interest of students in outer space. We would like to thank everyone else involved with the contest as well.
We also thank our advisor, Aditya Sengupta, the president of The Aerospace Society (Aeross) of our school (Delhi Public School R.K. Puram) for motivating us to go ahead with this project and for providing us his inputs regularly from time to time.

The project has been written from the perspective of a fictional company, Fletchel Constructors, inspired by the International Space Settlement Design Competition company of the same name. The initial conceptualization of the idea came from the Company History provided at ARSSDC 16 where the Fletchel history mentioned an underwater base as the company's first settlement meant for underwater farming. We would also like to acknowledge Ms. Anita Gale for the same.

FLECHTEL CONSTRUCTORS

Providers of:
- **Design and construction of entire cities on Earth**
- **Lunar habitat development; Mars base development**
- **Extraterrestrial materials refining and prospecting**
- **Columbiat and Astoria space settlements (with Dougeldyne)**

Flechtel Constructors has been in business since the 1920's, when it designed and built facilities for energy and chemical companies. The company has since been involved with building power plants, transportation infrastructure, farming, amusement parks, harbors, airports, and entire cities. Flechtel designed and built the Kenyan veldt launch site and Dougeldyne's Pacific Ocean launch site, then assisted with upgrades to accommodate new launch vehicle designs. A large percentage of its business in the 2020's resulted from its leadership in developing designs for modifying airport facilities to service aircraft with cryogenic fuels. A consistent company philosophy is that every customer is important, and no project is too big, too small, or too strange.

The company gained humanitarian recognition in the 2030's, when it demonstrated feasibility of huge ocean farming systems to grow fish and aquatic vegetables. Now scores of these installations operate in remote deep-water areas of the Pacific and Indian Oceans, far from land and pollution. These farms assure virtually inexhaustible food supplies for Earth's peoples.

Fletchel Constructors as in the Program Book of ARSSDC 16.

The project is written as a proposal set in March 2032, assuming certain infrastructure that are mentioned as the proposal progresses.

1 Basic Requirements

1.1 Scenario

Our mother Earth is made up of just 29% of land, which humans have exploited to the best of their capabilities in the past few centuries. As a result of deforestation, the total forest cover fell to only 40.32 million sq. km in 2010. Environmentalists all over the world slowly started drawing attention towards forest conservation and the rate of deforestation came down marginally. Despite this, only 39.84 million sq. km of forest cover is left as of 2030. *[R d'Annunzio, 2015]*. Governments all over the world put strict laws on deforestation rendering the growth of cultivable land virtually impossible. Fletchel Constructors realized the intensity of this fact noting the rapid growth in population from 6 billion in 2017 to 8.3 billion in 2030 *[World Agriculture Report for 2030 Estimation]*. Seeing that land was no longer a means of growth, Fletchel Constructors began its research on the prospects of an Underwater colony that could kickstart large scale underwater habitation and agriculture. Anastasi is a huge step forward from the pre-existing underwater habitats which are small in size and concentrated towards a single function. Anastasi is an example for the whole world signifying the immense diversity of advantages of underwater settlements through a single expandable settlement. The city will also improve the case for future space settlements, showing that humans are capable of expanding their frontiers to inhabit what's considered the uninhabitable.

1.2 Executive Summary

Anastasi will lead the way in solving not only the world's environment and agriculture crisis, but also the impending energy shortage due to the drying up of oil wells. Anastasi is an underwater colony in the Dead Sea at 31.51 degree north and 35.52 degree east at a depth of 260m. (Calculated using Google Earth). It is aimed at:-

1. Commercial Production of Crops.
2. Mining of Deuterium for Nuclear Power Generation.
3. Utilizing one of the few left Oil Reserves of the world in the Dead Sea.
4. Desalination and Cleaning of the Dead Sea to promote the growth of Natural Life.
5. Selling salt obtained from the Desalination process.
6. Setting up of various research labs to monitor under-water life and Dead Sea organisms.

7. Leading the way for future underwater settlements
8. A relatively low cost simulation of an orbital space settlement and a training center for humans going on the first space settlements.

Anastasi draws hope from the success of the Kazakhstan Government in recovering the Aral Sea which had drastically reduced in size due to the ecological disasters in 1960 through the Dike Kokaral Dam. It is also based on the success of the Red Sea-Dead Sea Canal which has pumped in water from the Red Sea into the Dead sea and managed to reduce the salinity of the Dead Sea to less than half of its value in 2017. Inflow of industrial waste through the Jordan River into the dead sea has been stopped and the water is cleaned before flowing into the Dead Sea. Anastasi will continue to improve the quality of water in the dead sea by enclosing areas to the point where fish will be able to survive in its waters. Since this will have a huge benefit on coasts around the Dead Sea where people will start migrating for new job opportunities, help from the Jordan and the Israeli government can be expected. Even though involvements of governments increases the duration of the process and also makes the contractor credible to them, their financial and resource based help will be essential for the setup of Anastasi.

1.3 Naming

Anastasi is the greek word for “resurrection”. This is in direct agreement with our goal for the project that is to “resurrect” the “dead” sea and build industries around it. Anastasi will essentially help raise water levels in this body and decrease its salinity and will make efforts towards introducing life to the dead sea so that it gets revitalized. Anastasi not only gives life to an otherwise dead body, it also proves the possibility of an underwater settlement and can help Fletchel Constructions in expanding underwater operations. It also serves as a motivation towards the success of settlements with artificial life support, and can surely help reduce the opposition to funding space settlements.

1.4 Location

1.4.1 Major Factors for Basic Location

For deciding an appropriate location for Anastasi, many factors had to be considered and evaluated. The aim always was to create a massive project that will give a huge push to underwater businesses. Agriculture was the primary objective. Conditions where it wasn't too cold were also necessary to make EVA operations easier. Business opportunities were very important too to fund the project. As the project was sure to create local employment opportunities while also using local resources, Government approval and help played a huge role. The settlement also had to be made self sufficient, it was necessary that it performs most of its sustenance operations on its own with minimum support from land after construction. And then came the Humanitarian factor, environmentalists opposing such projects had to be shown that investment in such projects CAN make a change for the better. A variety of fields had to be addressed to display the diversity of opportunity in such settlements and open more public initiative towards these. Any innovation comes with criticism and it is important to silence this criticism so that future development is not hampered. Change is not welcomed quite often and the primary obstacle towards change is proving that the change will improve society.

The Fusion industry is expected to be the leading sunrise industry in the coming years. Deuterium is not only needed for current Deuterium-Tritium Reactors but with Lunar Helium-3 Mining projects showing potential, Deuterium demand is expected to rise exponentially. It was decided that Deuterium mining would be an important part of the settlement. This Deuterium would be primary sold to Aerospace Companies looking to invest in fusion propulsion research. Making fusion propulsion spacecrafts possible would be a huge boost to improving our presence in space and it would not only reduce future launch costs, but also cut travel times.
Endorheic basins have a higher concentration of Deuterium as the water escapes these bodies only through Evaporation. Usually Deuterium being heavier than Protium settles in the lower parts of the water body. Therefore, as evaporation is a surface phenomena, it takes up more Protium water than Heavy water. Bodies which lose water only through evaporation thus have a higher Deuterium concentration by almost 3 times. *[Something Surprising Blog, 2012]* However, Deuterium would naturally be plentiful in deeper parts of these basins and this created an important aspect for further narrowing down on locations. A water body was required which had a suitable maximum depth for the setup of Anastasi so that the project could be setup in its deeper parts. This maximum depth was fixed at 150-400m to not only support a multi-level design which would reduce the need for buoyancy of the settlement, but also to ensure that pressure did not become too difficult to handle. Narrowing down on Endorheic basins thus helped in getting the difficult first push towards pinpointing a location. Areas with extreme conditions were then eliminated to facilitate EVA operations. It was also important to see which governments are actively looking for establishing water projects as negotiation would be easier with these governments.

Energy was the next major concern. Any underwater settlement of the size of Anastasi would require a lot of power. For this, buying energy was not seen as appropriate. Anastasi would have to generate its own power. Tidal Energy and Oil drilled from the sea were seen as the only viable options that could provide for the requirements. Tidal Power was obviously appreciated as Oil would again bring environmentalist concerns as oil reserves are depleting at a rapid rate. It was decided that if an oil mine would be dug, it would not be on a commercial scale and would drill at a rate required for the functioning of Anastasi and to pay off loans to companies that provided the energy during the construction. Setting up dams on rivers to generate electricity has seen a lot of criticism in recent times which would have caused problems in getting the project approved.
This helped eliminate a lot of lakes & rivers which did not have any oil reserves and of course no tidal energy prospects.

1.4.2 Dead Sea

After considering all these factors, the Dead Sea (an Endorheic basin) was chosen after much deliberation. The Dead Sea's potential is often underestimated and people pass it off as a 'lifeless body, with no fish and plants, just useless microbial growth'. Anastasi was never meant to be a project to take a good scenario and make it better. It was always meant to create a good scenario and to improve on it. The dead sea provides excellent conditions with moderate temperature waters. The high salinity and water density is useful as it makes diving operations with heavy suits easier reducing the need for floatation mechanisms. Israel, Jordan and the West Bank have been looking for projects to improve industries around the Dead Sea and are open towards funding such projects. The lack of marine plants and fish does not have major effects on the settlement as Agriculture has to be practised in closed structures in any case to prevent water flooding and pressure problems. Anastasi plans to enclose areas of the dead sea and reduce their salinity so that natural underwater fish and plants can be grown as well.

The Dead Sea also provided the unique chance of revitalizing a body which has "no hope" to bring huge amounts of trust towards the success of underwater habitats. Such a location would make the job tougher but the reward of success would be much greater. Being able to improve the environment while practising commercial business is a great achievement which can increase the prestige and reputation of Fletchel Constructions exponentially. The Dead Sea is a largely unexplored sea and tourism infrastructure will provide a unique experience.

The Red-Sea Dead-Sea canal has increased the maximum depth from 306m (at the time of its initiation, 2017) - 320m (As of 2033) *[Extrapolation based on the expected capabilities of the canal]*. This depth is ideal and the temperature conditions ranging from 10 degree Celsius - 25 degree Celsius over the year will not require major heating mechanisms as often needed in other bodies. Pressure would increase 1.3 times faster than normal as we go deeper due to the added density of salt but this can be combatted with stronger resistant material.

The Dead Sea will be made inhabitable for marine life using a big desalination pump. Salt will be separated and sold whereas the excess fresh water after a necessary amount for the settlement's own usage has been separated will be pumped back. This will make the water in a 1 km radius fit for sea-life in a decade and life can be introduced and contained. This will not only win praise from environmentalists but also provide satisfaction. A lot of energy will be needed for the desalination process and this can be

obtained from the untapped oil reserves identified in the Dead Sea. Unfortunately the Dead Sea does not have much tidal activity due to the high density and low volume of water. However it is understood that not everything can be obtained in a single location.

The Dead Sea also provides major research prospects in its deeper parts on microbial life that has survived in the highly saline and dark conditions where other organisms couldn't survive. Their study can help a lot in the field of biology and extremophile research.

Even though the location chosen is risky and untapped, it certainly has large prospects. It is an amalgamation of various factors which led to the decision. While it cannot be said that the Dead Sea is a perfect location, it does show potential!

1.4.3 Further pinpointing of the location

After deciding on the dead sea, another hurdle was pinpointing the exact location of the settlement. After analyzing the various opportunities of the Dead Sea, it was decided that a location with a depth of around 250-300m will be needed for Anastasi. Proximity to land was an important factor to facilitate construction and maintain contact. A gentle slope of the surrounding seabed was also a factor. Oil reserves played a very important role. Areas in the 250-300m depth range which were close to the shore were marked out. Geologists were hired to study the oil reserves in these areas. After studying thoroughly, a final call was taken on the exact location of the settlement. (*It is assumed that the given location has oil reserves as research on the same is not available*). It was decided that **Anastasi will be constructed in the Dead Sea at 31.51 degree north and 35.53 degree east at a depth of 260m with a minimum distance of 3.1km from land.**

1.5 Population and Work

Anastasi will have only a working population with no children to preserve a work based environment. Married couples will be allowed however they will have to separately arrange for their children if any. Mothers will be given maternity leave if required for the same. Population has been assigned to ensure 24/7 functioning of the settlement in 2 shifts so that maximum work output is obtained. The population breakup has done in the following table:-

Work	**Count**	**Description**	**Qualities Needed**

Deuterium Level Maintenance	8	Maintenance of mining and processing setups of Deuterium including handling of repair bots. No operations in the water.	Mechanical Engineering + Automation Control
Deuterium Mining Research	6	Research on properties of deuterium and on improvements for the mining process to enhance output. Also have to make charts on amount of deuterium mined and have to make reports on the proper functioning of the setup. No operations in the water.	Chemistry + Statistics + Management
Research Labs maintenance	6	Will have to repair and update systems in the Research Lab according to needs and draft technological advancement needs so that they can be imported from land. No operations in the water.	Robotics + Electronics + Automation Control
Research on Dead Sea Life	6	They will undertake research on the organisms that have survived the highly salty conditions of the dead sea and have made it their habitat. They will try to take genes from these species and use them for specific purposes. No operations in the water.	Biology + Bio-tech
Research on underwater conditions	6	They will undertake research on pressure, atmosphere, temperature conditions underwater and also study samples of the sea-floor. No operations in the water.	Geology + Oceanography
Research Ground Operations	6	They will go outside the settlement to help the researchers inside to get various physical samples and they will do ground research.	Diving + Underwater Navigation + Research
Oil Submarine Maintenance	8	They will go outside the settlement to regularly maintain the oil rig and will also control the submarines navigation.	Submarine Navigation + Mechanical Repair + Diving

Oil Mining Research	6	They will research on possible oil reserves for the submarine to exploit and also keep a constant check on the amount of oil being mined. They will form reports on the same and ensure that the reserves are not overexploited. No operations in water.	Geology + Statistics + Management
Oil Refining Maintenance	6	They will maintain the oil refining setup and also handle repair bots. They will implement technological upgrades when required. No operations in water.	Mechanical Engineering + Automation Control
Power Generation Maintenance	6	They will maintain the power generation systems and ensure proper functioning of power transfer systems between levels. No operations in water.	Mechanical Engineering + Electronics + Automation Control
Vehicle Maintenance	10	They will ensure maintenance of vehicles that dock in the vehicle area and also navigate the manned vehicles/emergencies. Will not have diving operations.	Underwater Navigation + Robotics + Electronics + Automation Control
Vehicle level system maintenance	6	They will maintain the machinery and docking ports of vehicles using appropriate automations. No operations in water.	Mechanical Engineering + Automation Control
Human Exit Maintenance	6	They will maintain all operations and the airlock in the human exit maintenance area. They will monitor entries and exits. No operations in water.	Mechanical Engineering + Management
Storage Area Maintenance	4	They will ensure proper functioning of mechanisms and automations in the storage area. No operations in water.	Mechanical Engineering + Automation Control

Storage Logistics	8	They will ensure the storage is well supplied and will monitor incoming goods and outgoing goods. They will ensure no wastage or shortage takes place and that constant export is maintained. No operations in water.	Logistics + Management
Desalination Plant Maintenance	10	They will ensure that all parts of the desalination system are properly working and will regularly update them. No operations in water.	Mechanical Engineering + Automation Control
Desalination Research and Development	4	They will ensure that the desalination process is working optimally constantly tweaking methods to enhance the process. They will also make reports on amounts of salt generated, water desalinated etc. No operations in water.	Statistics + Chemistry + Management
Waste Processing System Maintenance	8	They will ensure that mechanisms related to waste processing are functioning properly and will control automated processes related to the same. They will also ensure that the waste mechanism is updated regularly and new ways to treat wastes are used. No operations in water.	Mechanical Engineering + Automation Control + Environmental Studies
Residential Area Maintenance	30	They will ensure proper functioning of the residential area and all of the automations working to keep it clean. They will also include doctors, shopkeepers, recreation managers etc. No operations in water.	Depending on Job, based on Human Factors.
Processing Level Management	10	They will ensure that appropriate amounts of food are used for the consumption of the population and that water is allocated wisely. They will create charts to monitor food needs and submit these reports. They will ensure wastage is reduced in the settlement. They will ensure that air and water cycles are	Dietician + Environmentalists + Logistics + Management

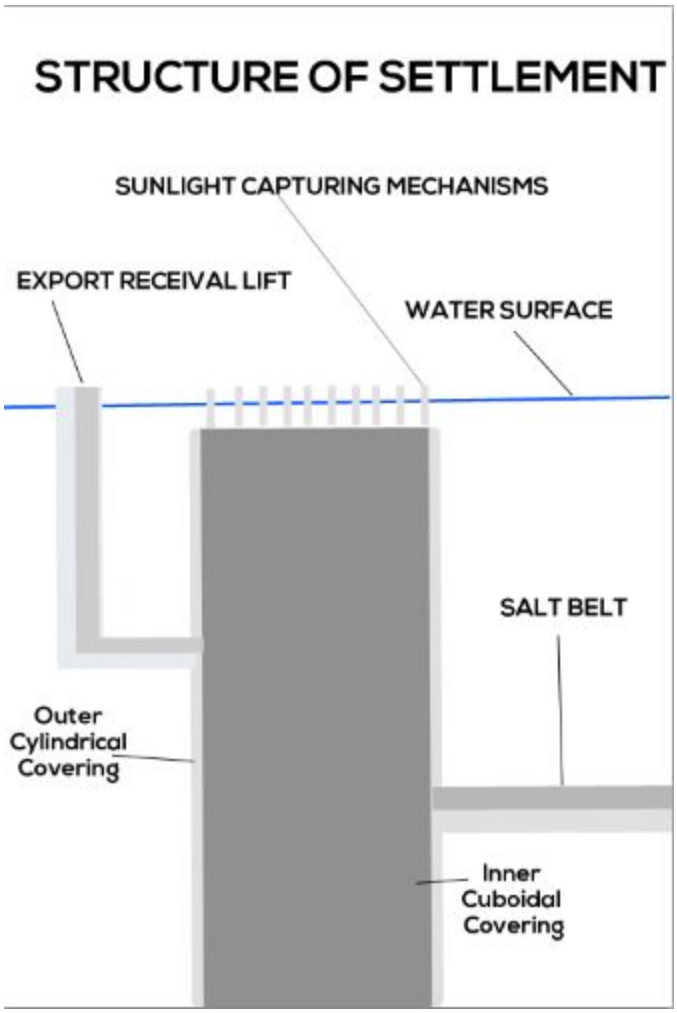
		functioning properly. No operations in water.	
Tourism Level Maintenance	8	They will ensure all mechanisms on the tourism level are functioning properly and will update these on advice from the tourism managers. No operations in water.	Mechanical Engineering + Automation Control
Tourism Management	8	They will not only guide tourists but also look for new innovative ways to increase tourism income on the settlement. They will make models and reports for the same. They can have EVA in the upper depths of the Dead Sea.	Tourism + Diving + Trainers in Diving + Management
Agricultural Research	12	They will monitor the growth of plants in the sea and create reports and papers on the same. They will understand varying effects on different plants and create varieties that grow better. No operations in water.	Biotech + Agriculture
Agricultural Ground Operations	10	They will run the different agriculture based machinery and even manually go inside the agricultural level to perform operations. No operations in water.	Agriculture + Automation Control
Agriculture Level Maintenance	12	They will maintain all operations in the agricultural level and perform repairs in-case of damages. They will also ensure that the agricultural bots are working properly. No operations in water.	Agriculture + Robotics + Automation Control
Sunlight Capturing Mechanisms Maintenance	6	They will ensure the proper functioning of the sunlight capturing mechanisms and perform repairs in case of damages. They can have work in water but only near the surface of water at low depths.	Physics + Repairs + Agriculture
External Repairs	16	They will maintain the external body of the settlement with operations in the water. They will make use of varying bots for repairs.	Diving + Repairs + Automation Control

General Security and Automation	16	They will keep track of security, robots and programmes being used in the settlement and update/debug them as per requirements. No operations in water.	Programming + Management + Robotics + Automation Control
Administration and Management	15	Each level (Excluding foundation, including submarine rig) will have a manager specifically focused on its operations. They will together administrate Anastasi through majority votes and discussions. They will make larger demands for the working of the settlement and make tie ups with different organizations. They will also write reports on the statistics of the settlement.	Level based requirement + Management + Business + Accounts
Total	**263**		

It is important to note that all crew members on the facility will receive three month briefings and trainings for their job before going on the settlement. They will be hired on contract basis and selected considering a variety of factors (not just the listed needed qualities). Their salaries will be fixed according to their performance and experience. Even though a total starting population of 263 is estimated, however initial setups will be constructed to cater for 300 people including the humans who will visit the settlement for space training. This will obviously expand in the future as the scope for the settlement increases and the number of humans requiring training to go to space also multiplies.

A gender or age based breakup has not been estimated as we do not believe in limiting our scope by these boundaries. Any and every deserving candidate will be given the chance to work on the settlement. Even though a younger population is expected for execution based work like repairs and ground operations, older people will be judged equally for the roles. Similarly, even though research and administration require experience which is usually found in people above the age of 40, younger people with merit will again be equally considered.

2 Structural Design



2.1 Settlement Structure

Anastasi will have a multi-level design as different functions of Anastasi have to be carried out at varying depths. The levels will be as follows:-

Level	**Depth**	**Function**
Foundation	260m(seafloor)-	The foundation of the whole settlement will be dug

	270m(under sea floor)	to a depth of 10m below the sea-floor for stability.
Deuterium	240m-260m	The deuterium mining setup will start from the sea floor and will have a height of 20m.
Research	230m-240m	A 10m high research facility will be built deep in the sea for researching about deep sea life of the dead sea and other deep sea research.
Oil Refining	210m-230m	Oil mined from the submarine oil rig will be brought in here through small container ships for refining. Oil will be stored here too.
Power	200m-210m	Power will be generated here for the functioning of the whole settlement.
Vehicles	150m-160m	Storage of Oceanic Transfer Vehicles for transport of all sorts of materials and also their exit point.
Human Exit	140m-150m	Area where humans will exit the settlement for sea operations.
Storage	130m-140m	Storage of all excess material on the settlement will be done in this area.
Desalination	110m-130m	Huge desalination mechanisms will be setup to obtain salt which is transported to land by the salt belt continuously.
Waste	100m-110m	All the wastes from the settlement will come here and get processed.
Residential	50m-100m	The whole crew will stay on this level. The level will provide for various facilities needed for comfortable living conditions.
Processing	40m-50m	Water management for the settlement, Air Control and Food processing takes place in this level.
Tourism	30m-40m	Tourist activities will take place in this area including

		underwater aquariums in desalinated water.
Agriculture	10m-30m	Multiple Agriculture levels will be created using light captured through the upper sunlight capture system.
Sunlight Capture	-1m(above surface) - 10m	Sunlight capturing mechanisms with increased surface areas will be setup which take light to agricultural areas through multiple refraction.

Apart from this a portable submarine oil rig will be setup which will be regularly maintained by the crew on Anastasi. The submarine will operate in deep areas within a 1km radius of the settlement and will change its position whenever the target oil reserve dries up. Separate Human and Cargo Transport lifts will be made between the cuboidal levels and the cylindrical covering to ensure transport between different levels working at a very high speed. Water supply will be ensured using pipelines whereas energy supply will require a complex powerline setup.

2.1.1 Exterior Design

The structure of Anastasi will basically be a cylinder of radius 282.842m and height 260m with an inscribed cuboid of dimensions 100mx100mx260m in it.

A cylinder was chosen for the outer body as pressure inside water is minimum on a curved surface. The outer walls of the cylinder which will be curved will be the surface where the pressure of the water will act. This reduces the pressure on the walls of the settlement as water molecules get more area to act on and area of contact is inversely proportional to pressure. The cylinder acts as a pressure protection mechanism for the inner cuboid.

The inner-cuboid will actually have the interior designed levels. The surrounding cylindrical volume will be used for transport lifts and pipelines. The real multi-level design will be made inside this cuboid volume. Another volume with a square cross section was required for the real work areas of the settlement as cylindrical down surfaces with small areas (Earth is a sphere but its sheer size makes the curvature seem non-existent) are difficult to work in for humans as the human brain is accustomed to rectangular down surface designs despite the spherical nature of our earth. Also, the quadrilateral with the maximum area when inscribed in a circle is a square. This allows for more availability of down surface area for the main settlement. The square cross section also allows for easier calculations and designs of the various levels on the settlement. A second inner wall also means that in case water manages to enter through holes in the cylindrical outer covering, it will have to go through the cuboidal layer to cause damage. This will

allow enough time for fixing the damage. Anastasi being a settlement fixed to the ground like a building requires such measures as it is not mobile. Also, the cuboidal shape extends to come directly in contact with the outer cylinder in some areas such as the airlocks and vehicle entry areas.
Apart from this, a salt belt will come out from the settlement at a depth of 120m (Desalination Level). Also, an Export Receival Lift will also come out from the storage level. Anastasi will also have sunlight capturing systems on the top. Further explanation of all this has been given in the following sections.

2.1.2 Level Description & Area Allocation

The various levels of Anastasi inside the cuboidal volume have been divided in such a way that mechanisms for different operations are systematically separated and not clustered. All levels have atmospheric pressure and normal land like composition of air except the Agriculture level (The sunlight mechanisms have no artificially induced pressure as they are basically mirrors and tubes). The following subsections show the level designs in order from top to bottom (sea surface to seabed).

2.1.2.1 Sunlight Capture Mechanisms

The sunlight capturing mechanisms will be present above the surface of the water at a height of 1m. They will be spread across an area of 120mx120m and will use multiple refraction of light to concentrate light into tubes that will transport this light to the various agricultural levels. The refraction mirrors will be angled in such a way so that sunlight gets concentrated on the surface of the tube. These mirrors will be made of polished aluminium which can reflect 99% of light falling on them. The tubes will be made of lenses of a refractive index that ensures total internal reflection of light. 95% of the initially captured sunlight will make it to the various agricultural floors.
The need for sunlight capturing mechanisms arises from the fact that water absorbs light very fast. Only the first 15m of the Dead Sea water get enough Red Spectrum light needed for growth of plants. Moreover, to practice multi-level farming (so as to reduce the flat area required), light has to be provided on each level. The top level will use all the light falling on the area and the lower levels will not be able to receive sunlight without the use of these tube systems.
The tube systems will directly cut through the cylinder covering and will enter the agriculture area through holes where the light will be released. This obviously means that sunlight will be provided only during the day hours as on land.

The sunlight capturing mechanisms will be maintained constantly by a dedicated Sunlight Capturing Mechanism repair team. Their quality and efficiency will be enhanced from time to time as technology advances.

2.1.2.2 Agricultural Level

The 20m long agricultural level will be divided into 5 agriculture stories each of height 3m with a 1 m separation in between. Roots of the plants will be inside this 1m separation. The agricultural area will have an atmospheric composition of 75% nitrogen, 22.5% oxygen, 1.5% carbon dioxide and 1% of other gases. This is a little different from normal atmospheric conditions as more carbon dioxide is needed for better photosynthesis. However, increased carbon dioxide levels can hamper nitrogen intake of plants thus affecting their growth which is why the carbon dioxide levels were limited to 1.5%. *[University of Gothenburg, 2015]* Plants will grow in hydroponic systems as ample freshwater will be available from the Desalination pump. The agriculture level will have normal atmospheric pressure (1atm). It will have paths for bots to move in and also for humans when they will be required inside the level. Each floor will have a down surface area of 100mx100m out of which 1000m^2 area will be used up for bot/human paths. It will ensure proper growth of plants in a clean environment. It was kept at a higher depth to keep the construction costs for the sunlight mechanisms low as lower lengths of tubes will be needed.

2.1.2.3 Tourism Level

The tourism level will be the headquarters for all tourism activities. It will have an underwater museum and will have space for construction of the underwater aquarium. Activities like Swimming while connected to the building will take place on this level. The tourism level will have a mini-airlock system to allow people to move in and out. It will also have offices of the tourism-related crew. Transparent Alumina and Transparent Composite Material windows on both the cylindrical outer covering around it as well as the cuboidal wall will allow for sea-viewing experiences. The tourism level will have a 100mx100m down surface area out of which 3000m^2 will be used for the museum, 3000m^2 will be reserved for the aquarium construction, 1000m^2 for offices, 1000m^2 for training for tethered swimming, diving activities etc, 1000m^2 for canteens and mini-recreation and 1000m^2 for the saturation system, airlock and stowage. It has been kept at a relatively higher storey so that tourists do not have to go deep into the sea and expensive pressure protection for Tourist swimming is not required. The recreation diving equipment as mentioned in section 3.6.2 will be used. Also the water at this depth will have more sunlight than deeper waters which reduces the costs of lighting, even though artificial lighting will still be present in sufficient amounts for visibility. The

enclosing of the area around the settlement for desalination and aquaculture will also allow beautiful marine life views.

2.1.2.4 Processing Level

The water, food and air processing level will be where the agricultural produce will be processed and the wastewater from waste management level, fresh water from desalination level etc. will be managed. Large systems will be setup for management of these. Agricultural produce will be separated into Anastasi consumables and commercial export crops. Crop wastes will be sent to the storage level for packaging so that this waste can be sent through boats to land to clear it from Anastasi. The down-surface area of this level will be 100mx100m out of which 3000m^2 will be used for Food, 4000m^2 for Water, 1000m^2 for offices and 2000m^2 has been saved for future expansion. The activities in this level have been further described in section 3 Operations. Transfer of water will take place through pipelines in the volume between the cylindrical covering and the cuboidal levels. Food will be transferred using cargo lifts also in the same area. Air purification and management systems will be present on this level as well.

2.1.2.5 Residential Level

The residential level is a 50m long level further divided into five 10 m long sub levels (including separations). This level will host the residential quarters of all crew on Anastasi along with facilities and offices for some of the population. All residential levels will have a down-surface area of 100mx100m and the allocations have been further explained in the section 4 Human Factors.

2.1.2.6 Waste Management Level

The waste management level on Anastasi will treat Bio-waste, E-waste, Human waste etc. Maximum focus will be on recycling wherever possible however wastes that cannot be processed further will be sent to the storage level for packing and will be sent to the boats in tight boxes for further processing on land. A down surface area of 100mx100m has been provided. Activities on this level have been further explained in section 3.4. Waste pipelines will be present between the cylindrical outer covering and the cuboidal levels.

2.1.2.7 Desalination Level

The desalination level on Anastasi will have waste desalination mechanisms along with mechanisms to separate important minerals from the separated salt like magnesium which has been used extensively for activities of the settlement. The salt belt also comes

out from this level and ends at land. The level has been divided into 3 levels of height 10m, 5m and 5m respectively for division of work and to maximize surface area. The highest sub-level will have the water storage tank and will be extended to include the volume between the cuboidal levels and the cylindrical covering. Water will enter from this extended side and will go to the tank. Each level has a down surface area of 100mx100m spread across storage tanks, machinery, reverse osmosis systems, mineral separation systems etc. The level is deeper in the sea as the salt density increases with depth between a depth of 35m-90m in the dead sea. After this it slowly stabilizes. *(Wikipedia - Dead Sea)* The activities on this level have further been described in the Operations as well as Business Development section.

2.1.2.8 Storage Level

This level has the storage and packaging mechanisms for all the products of Anastasi. It is connected to the Export Receival Lift and also has been divided into two sub-levels of height 3m and 7m respectively. The 3m level is the packaging and dispatch area whereas the 7m level is the actual storage area. This Level has all the excess supplies, commercial products, logistics and management of goods and other related functions of the settlement. Each sub-level has a down-surface area of 100mx100m with the storage level further divided on the basis of different types of storage. Paths will be defined for bot/human movement and will take up an area of 1500m^2. The packaging level has various packaging apparatus and machinery and also the release of the Buoyancy Bubbles etc. It too has a down surface area of 100mx100m.

2.1.2.9 Human Exit Level

The human exit level has the Saturation system at one end and the cuboidal area is extended to include the cylindrical gap volume. It has offices in the centre along with the upper stowage as the area has been divided into 2 levels of height 7m and 3m with the upper area for storage of equipment. The human exit level has a down surface area of 100mx100m and its activities are further explained in the section 3.6.

2.1.2.10 Vehicle Level

The vehicle level is not divided vertically into sub-levels. It is used for storage of vehicles including the Oceanic Transfer Vehicle (OTV). It has the vehicle exit airlock which basically increases the pressure inside a particular walled enclosure to levels more than the outside water so that water does not enter. The vehicle airlock has security scans to ensure that no harmful substances are brought inside. It also has detailed maintenance procedures. The vehicle level will also be used for research on upgradation and new vehicle designs needed for future expansion. Parts of the submarine oil rig will also be

prepared, repaired and upgraded here. The vehicle level has a down surface area of 100mx100m.

2.1.2.11 Power Level

The power level will cater to the power needs of the whole settlement. It will generate power using petroleum refined from oil drilled by the submarine rig. Transfer of power to the whole settlement will take place through power lines in the volume between the cylindrical covering and the cuboidal levels. The pollutants released in the generation of power will be captured and separated in the waste management level. The carbon dioxide will be used for plants while some of the harmful material will be concentrated in crates and sent to the land through boats for management. The power level has a single floor of down surface area 100mx100m.

2.1.2.12 Oil Refining

The oil mined from the submarine power rig will be refined here. The oil refining level has been sub divided into 2 levels of height 10m. The chemicals released in the refining process will be treated by taking them to the Waste Management area and following procedures like those for in the Power Level. The down surface area of each level is 100mx100m. The Activities on this level have been further described in section 5 Business.

2.1.2.13 Research Level

The research level will be used for research in various fields. Labs, Observatories, Sensors etc. will be set up around this level. It will also serve as the network communication hub of the settlement with main servers based here. The SONAR of the settlement will be attached to the exterior part of this level. It will be used for generating under-water maps which will be installed later into all navigation systems. The level will also be used to monitor the response of the humans on the settlement to collect data for future space settlements. Humans who join the settlement for space training will also be monitored. The down surface area of this single storey level will be 100mx100m. The activities on this level have been further described in section 5 Business.

2.1.2.14 Deuterium Level

The Deuterium Level will be used for taking in water and separating Deuterium. The separated deuterium will be packed and sent to the storage area. The deuterium level has been separated into two levels of height 8m and 12m. The 12m level (lower) will have the storage and first stage of separation whereas the lower level will have the later

stages of separation. The down surface area of each story is 100mx100m. This was chosen as the deepest level as Deuterium being heavier than Protium settles down at the bottom. The activities on this level have been further described in section 5 Business.

2.1.2.15 Foundation

The foundation of the settlement will be the first thing to be constructed. It will be dug deep into the seabed to a 10 m depth below the seabed. This is necessary to ensure the stability of a very long and heavy settlement. The foundation level will be maintained monthly by adding a coat of graphene to reinforce the foundation. The foundation level will be made of a solid block of stainless steel and concrete with dimensions 100mx100mx10m. This will be strong enough to hold the entire weight of the settlement.

2.1.2.16 Cylindrical Volume

Power lines, water pipelines, communication lines, waste pipes etc. will be set up in the volume between the Cylindrical covering and the Cuboidal levels. 4 cargo lifts that can go from the top to the bottom in just 1 minute with capacities of 5000 kg have been built. 6 Human lifts with capacities to hold 10 people at a time, (1000kg) have been built that can go from the top to the bottom of the settlement in just 45 seconds. These lifts will ensure smooth transport between various levels of the settlement. The cost of each human lift & cargo lift is estimated at $1,000,000 amounting to a total of $10,000,000. The cylindrical volume will be fully utilized.

2.1.2.17 Desalinated Enclosures

Transparent desalinated enclosures will be made to enclose areas where water is desalinated and fresh water is released thus reducing the salt content and allowing marine life to thrive. Walls will be made of transparent composite materials on all 4 lateral sides. These walls will be fixed to rollers, which will go deep into the seabed. Whenever the enclosure has to be expanded, a thruster system on the rollers will be fired and the walls will slowly shift outwards. The walls will have extensions nested within them which will retract out and thus fill the gaps that are created during this expansion. Further transparent panels can be constructed and then assembled under the sea to fill in the walls. Thus, the enclosure will keep on expanding as time progresses and more area will be available for aquaculture.

All these separate setups will ensure for a healthy maintenance of production and research of the settlement.

2.2 Construction and Assembly

Fletchel Constructors

Anastasi will certainly be the biggest underwater construction process ever undertaken. A 260m long structure is not only costly, but time consuming to build. The research, design and construction for Anastasi will begin the day the contract is awarded i.e. in 2032. The foundation of the settlement will be dug into the sea floor by August, 2034. Construction of the Submarine Oil well will begin in May 2034. Meanwhile construction of the outer body of the settlement will take place on land. The cylindrical with inscribed cuboid module (explained in Structural Design section) of each level will include the walls and ceiling and will be constructed one by one and will be lowered into the sea by ships while humans underwater ensure the level is fixed to the lower one by automations. Each level will be built as a module which can be joined to another level module using spikes present on the bottom of each level and holes on the top of each level with adhesives. The first level, which is the Deuterium level will be dropped into the sea by September, 2034. By January 2035, the top agriculture level would have been dropped and fixed. Next, the interiors in the residential level will be constructed on land and the agricultural level, waste level, power level and food/water level will be set up too. By November, 2035, Humans will shift to the residential area and agricultural operations in the top agricultural floor (10-15m) will begin. Storage will be done on the residential level itself for the time being as it will not be filled to its full capacity. Fuel for energy supply during this period will have to be bought as the Submarine oil well would still be under construction. Construction of the Transport Lift begin next and it will be completed by February 2036. Sunlight Capturing Mechanisms will also be setup in February 2036 and commercial agriculture will begin in all 4 sub levels of the Agricultural level. The Desalination Level, Storage Level, Human exit level, Vehicle level, Oil level and the Deuterium level will be constructed next with parts being imported from land and assembled by the already residing population on Anastasi. These levels will be completed by January 2037. The submarine oil well is expected to be ready by then too and it will be finally launched after testing. Proper operations of all these facilities will begin after testing by March 2037. The Research and Tourism level will be constructed next. During this process, the transparent enclosing of the ocean area using the roller walls mechanism described earlier will be done for the first 0.1km^2 of sea. This will continue to expand at a projected rate of 0.1km^2 per 0.01km^2 every month so that by 2050, 1.6km^2 of sea around Anastasi will be desalinated and will be inhabited by aquaculture systems. **By December 2037, all parts of the initially proposed Anastasi design will be ready and functioning**.

It is important to note that the Hofstadter's Law *("It always takes longer than you expect, even when you take into account **Hofstadter's Law**.")* has not been accounted for as accounting for the Hofstadter's Law would open a further margin for delay as our

perception of the completion time would automatically increase. We will aim to complete operations by our deadline and try to leave no scope for delay.

Construction and Assembly would require constant assistance from local ships and divers who will be given contracts. The construction crew will be largely disbanded after the construction of the project is complete. Since not many ships sail on the Dead Sea due to its small size, contractors will have to be hired in the Red Sea area to shift their infrastructure to the Dead Sea during the construction phase.

2.3 Materials for Construction

Anastasi being a settlement with parts deep under water needs to have a very strong structure and outer coverings that do not rust. Structural strength, pressure resistance, a non-porous outer covering are some of the important features needed to maintain the settlement. All materials will be procured from the local area for construction. The companies will either be paid directly or will be given subsidized materials produced later once Anastasi is completed. The cylindrical outer covering as well as the inner cuboidal wall will be 1m thick to ensure stability of the structure.

2.3.1 Cylindrical Covering

The cylindrical covering will be 1m or 100 cm thick. The following table describes the materials used from outermost moving to inner materials:-

Material	**Thickness**	**Features**	**Quantity**
Copper-Nickel (90-10)	15cm	Very low Corrosion Rates, Good Tensile Strength	69290.33 cu. m
Rigid Polyvinyl Chloride	9cm	Waterproof, Cheap, Rigid	41578.66 cu. m
Magnesium Alloy	10-30 cm	High Tensile Strength, Obtained on Settlement, Low Density	92379 cu. m
Steel	10-20cm	Cheap, Provides Structural strength	64192.45 cu. m
Asphalt Concrete	35-45cm	Easily Mouldable, Cheap, Readily Available	184692.77 cu. m

Rigid Polyvinyl Chloride	1cm	Waterproof, Cheap, Rigid	4620.50 cu. m

The magnesium alloy layer will have a thickness of 10cm in the upper parts of the settlement. However as we go deeper, this thickness will increase to 30 cm taking thickness off from the steel layer and asphalt concrete layer. This is because pressure increases as we go deeper in the sea and better pressure-protection materials will be required. Polyvinyl Chloride (PVC) will be used twice, first for waterproofing against sea water in the outer layers (thicker) and then in the innermost layer to protect the asphalt concrete from inner moisture. Asphalt is spewed out by the Dead Sea and is collected for local industries. This will be mixed with the concrete for added structural strength. Magnesium has a high concentration in sea salt and will again be taken on loan from magnesium companies around the settlement for construction. These companies will be repaid in kind later when the magnesium produce in the desalination plant will be sold to them. Apart from these wall materials Piezoelectric materials will be used for Hull-breach detection and Automated Aerogel Sprays will be used for temporary reinforcement.

2.3.2 Cuboidal Levels

The cuboidal level will have different materials for walls, level/sublevel roofs, flooring etc. Some levels like the power level which generate a lot of heat will have special thermal insulation materials. In levels which have been extended to meet the cylindrical covering, no cuboidal wall is present. The material used in the cuboidal level will be bent more towards structural strength than pressure resistance as seen in the Cylindrical outer covering. The cuboidal wall materials can vary over different levels as per the needs of the levels. However some basic materials remain the same and are listed below:-

Material	**Function**	**Feature**	**Quantity**
Rigid PVC	Wall Waterproofing	Waterproof, Cheap, Rigid	9712 cu. m
Flexible PVC	Waterproofing in complex design parts	Waterproof, Cheap, Flexible	5414 cu. m
Asphalt Concrete	Structural Strength in Walls & Level Ceilings	Mouldable, Cheap, Readily Available	108142 cu. m
FiberGlass	Strength & Coatings	Strong, Light,	1966 cu. m

		Mouldable	
Steel	Structural Strength	Strong, Cheap	27555 cu. m
RTV Silicone	Join Different Levels	Adhesive	446 cu. m
Polyurethane	Join different Levels, Thermal Insulation	Adhesive, Insulator	371 cu. m
Lead Zirconate Titanate	Piezoelectric Detection	Piezoelectric, Relatively Cheaper Ceramic	7223 cu. m
Transparent Alumina and Composite Mixtures	Outside Views	Transparent, High Tensile Strength	825 cu. m
Chemiluminescent Flooring	Light up flooring materials good for Power cuts	Strong, Light up using Chemical reactions inside.	45000 cu. m
LED Fabric	Sky-like effect in Ceilings	Luminsicent, Strong	10092 cu. m
GLARE	Fire-Resistance. Used in inner parts of walls.	Strong, Light, Fire & Corrosion Resistant	46291 cu. m

2.3.3 Sunlight Capturing Mechanisms

As described above, the Sunlight capturing mechanisms will use Polished Aluminium for reflection and lenses for total internal reflection on the innerside of the tubes. The outer surface of the tubes will be 5 cm thick and made of PVC for Water-proofing and Magnesium Alloy for strength. The tubes will also have GLARE for heat resistance.

2.3.4 ERL (Export Receival Lift)

The export receival lift has walls which are 20 cm thick. These walls are made of Copper-Nickel (90-10), PVC, Magnesium Alloy and Asphalt Concrete.

2.3.5 Salt Belt

Fletchel Constructors

The salt belt has an outer protective wall which is 10cm thick. It is made of Copper-Nickel, PVC, Magnesium Alloy and Asphalt Concrete whereas the conveyor belt itself is made of Rubber.

These materials ensure a strong settlement with costs minimized wherever possible without a compromise in quality.

2.4 Exterior Repair

Exterior Repair operations of the settlement's body will be overlooked by humans. Whenever weakness in the structure is detected, a human along with repair robots will go to assess the situation and make repairs. For exterior repair operations, the AMADA suit will be worn. However, instead of using thruster systems which are difficult to navigate, 2 skateboard type systems will attach themselves to the exterior of the building and the human will stand on the lower board and hold on to the upper board. These will then move to the target area using thrusters. The lower board will have handrails to hold on to whereas the upper board will have a handhold too. The lower board will also have a cargo storage box for tools and other materials & Footholds for support. Robots will travel on these skateboards too. The skateboard will have 5x5m dimensions and will not need human intervention for navigation. The cost of a typical skateboard system including the safety holds and cargo box will be USD 2000 and 10 such skateboards will be present on the settlement.

While most repairs will be done by robots, humans might have to do some manual work at times. In these cases, traditional AMADA arms which do not have enough flexibility in the hands will not be used. Instead, Expensive Carbon fibre arms will be used which provide dexterity to the fingers. These arms will fit in with the rest of the AMADA suit. These arms will not be used on every mission as their maintenance costs are high and repairs would be costly. They will be 10 times more expensive than the traditional Magnesium Alloy arm. Repairers will be given the option to take these instead of traditional AMADA hand units however this will require approval from the base. These will also be used when required for submarine oil well repair operations. These arms will themselves cost USD 5000 and a total of 15 such arms will be on the settlement.

2.5 Expansion Capabilities

Anastasi will not only get upgraded technologically over time, but will also expand and facilitate construction of new structures around it. Though the design of Anastasi does not make it feasible to extend the cylinder and then extend the cuboidal levels, new structures can be constructed and connected to Anastasi. Also, space has been provided for expansion on all levels of the settlement. The aquaculture enclosure will be expanded by 0.01km^2 every month as mentioned earlier. The following are some of the ways and methods by which expansion can take place on Anastasi.

2.5.1 Magnesium from Desalination Plant

The desalination plant will produce an astonishing 3600 tonnes of salt every hour. 13.5% of this is Magnesium. A small percentage of magnesium will be separated for making alloys of magnesium used in various parts of the settlement (Eg: AMADA suit). Magnesium alloys can have tensile strengths up to 570 mPa and Magnesium alloys have low density. They can be used for construction of new settlements like they were used for construction of the main structure of Anastasi. When construction of projects will be decided upon, the magnesium separation plant will start working full time instead of its usual operation of 45 minutes a day (it is as low as this as demand will be quite low for the first 2-3 years). Thus, magnesium is one way in which the settlement can facilitate for construction of newer settlements around it.

2.5.2 Construction sub-settlement

Expansions adjacent to the Anastasi Settlement building will be constructed separately. The first sub settlement planned to be built after Anastasi's main settlement is the Construction Settlement. This settlement will lead construction operations for other sub settlements so that dependence on land is reduced. The construction settlement will be a seafloor settlement. It will consist of a central cylinder with a height of 100m divided into 5 levels, in which the top level will be a vehicle airlock and storage of height 10m and the level below it will have a human airlock and saturation system of height 5m. Five levels will follow each of height 17m and these will be used for construction and offices. A torus of radius 50m will surround this central cylinder and will be connected to it using spokes made of carbon nanotubes for pressure protection (they will be thin and hence strong material no matter how expensive will be needed). The torus will have the residential areas for 50 people who will be running the construction using bots. It will be directly connected to the main settlement's residential level with a travelator. This cylinder-torus design was chosen as a proper separation was required between the construction and residential area of this settlement and both the torus and the cylinder provide a curved outer surface to handle pressure. The design also ensures that the

settlement is light and that construction costs are minimized. The walls of the cylinder will have large openable areas so that constructed parts can be released into the water outside. These will then be taken to appropriate locations for assembly. The construction settlement will be an important aspect to future expansion of underwater habitats around Anastasi and its construction is expected to be initiated in the late 2040's.

2.5.3 Underwater Adventure Park

The underwater adventure park is one of the planned expansion settlements. It provides a good idea of depth-changing sub settlements that can be built around Anastasi for business and research requirements. The underwater adventure park is designed to allow views of the surrounding fish while enjoying rides for all ages. It will be the first of its kind. It will basically be a hemispherical structure with the base providing for buoyancy changing mechanisms. This base will have dimensions 20mx20mx3m. It will be made of the highly pressure resistant Magnesium Alloy produced on the main settlement so that the settlement can move deeper without pressure problems . In Fact, the settlement's constant change of position will be a feature for tourists as they get to visit various parts of the water meaning a variety in surrounding life. The upper hemispherical dome will be made of Transparent Alumina and composite materials which have a high tensile strength and can resist pressure as well. The transparency will allow viewing the surroundings. The base will be able to store water when it needs to sink and release it when it needs to go up. The adventure park will have all sorts of rides and will be pressurized at atmospheric pressure. It will come up to the surface daily in the morning so that people can enter and then drop down during the course of the day and come back in the evening to release people. Emergency evacuation oceanic transfer vehicles will be present in case someone wants to leave early. The adventure park design shows a possible floating settlement design for expansion.

The following provide a basic idea for what future expansions will look like around Anastasi. More planned future development ideas include:-

1. ***Dedicated Mariculture Settlement***
2. ***Moving Research Settlement***
3. ***Underwater Sports Settlement***

These could be stepping stones to transform Anastasi into an Atlantis like city in the future.

3 Life Support

3.1 Air

3.1.1 Air Control

The settlement provides all the essential conditions to the inhabitants to live and work underwater. Bell umbilical cords made of hoses will provide air, hot water and electricity.

Breathable air, the most vital condition for residing will be provided and maintained in the habitat. The breathing gases will be monitored by air regenerative systems. A bell umbilical will control gas supply.

Nitrogen which is present in large amounts in the air has harmful effects in water on the blood vessels at high pressure conditions. Nitrogen will be substituted by Heliox (helium and oxygen) mixtures. Helium cylinders or helium-hydrogen mixtures instead of nitrogen will prevent air bubbles in the bloodstreams of the residents. Helium will disperse body heat quickly and cause frequency modulation while speaking. High pressure cylinders will be present for gas supplies. Emergency supplies will also be kept having breathing gas mixtures.

Water supply will be used for electrolysis, decomposing water into oxygen and hydrogen gas. Breathable oxygen will be produced by this method in large quantities.

The reaction taking place is:

$2\ H_2O(l) \rightarrow 2H_2(g) + O_2(g)$

If brine (water sodium chloride mixture) will be used for electrolysis, chloride ions will be oxidized to chlorine instead of water oxidizing to oxygen. Therefore, purified desalinated water will be used for oxygen production and not chlorine. The hydrogen produced will either be burned and converted to water again or used in helium-hydrogen mixture cylinders. Hydrogen can also be used for storage of energy

and water in fuel cells. The oxygen and other gases will be pressurized into storage cylinders.

The oxygen will be stored in cylinders with other gas cylinders and in the Processing Level. They will also be installed in the saturation system and transfer capsules. Helium or Heliox cylinders will also be provided to divers. Gas reclaim systems will be installed in the settlement. Saturation diving is done on heliox mixtures by maintaining pressure of oxygen and removing carbon dioxide by scrubber cartridges. Helium is the main component, with a small traces of nitrogen and residuals from the air in the systems before compression.

Helium based breathing gas after the use will be recovered by reclaim systems which will help reuse them. The recovered gases after purifying are stored in cylinders after pressurizing. The closed gas reclaim systems can save gas costs and recover gas mixtures. Helium gas can be reused from divers' helium cylinders economizing cost and storage amounts. Lesser cylinders will be required and more gas can be recovered using this reclaim systems. The system will have a control unit which will adjust and monitor pumping and addition of oxygen and gas mixtures and diver supplies. A scrubber reprocessing unit will remove carbon dioxide and moisture. Gas boosters will boost the recovered gas pressure to storage pressure. The supply unit will ensure the supply in the settlement.

3.1.2 Pressure

Anastasi will be a closed pressure habitat having air pressure roughly equal to atmospheric pressure. This includes a saturation system having an airlock and moon pool for saturation diving and preventing decompression sickness, regulating entry and exit and maintaining pressure.

The pressure regulators will adjust and monitor pressure in the settlement and will also be connected to the gas supplies. These regulators will ensure atmospheric pressure in the residential block and will also maintain ambient pressure when the hatch opens for water supply in the transfer chamber.

The main residential block will have partial pressure of oxygen around 0.40 bar. Carbon dioxide will be recycled and maximum level 0.005 bar partial pressure. Nitrogen partial pressure will be around 0.78 bar but will be decreased over time and topped with helium.

The saturation system will have a transfer chamber acting as an airlock which will control pressure between the atmospheric pressure in the residential block and ambient pressure of the water. The moon pool will allow water to enter through the hatch and will

maintain ambient pressure when the water enters the supply lock. The recompression chamber will be accessed in case the diver suffers from decompression sickness. The diver will be treated here by adjusting the pressure.

3.2 Food and Agriculture

The population and bots will contribute in various agriculture techniques for producing sufficient amounts of food. The food produced will be enough for the settlement's requirements as well as transporting to the surface.

The agricultural block will be present above the residential block. It will be divided into different chambers and vertical levels for cultivation of different plants using different methods.

3.2.1 Methods of growing

Hydroponics

In hydroponics, the plants will be grown in a mineral nutrient solution or an inert medium without the use of soil. This method will increase the growth rate and productivity of the crops to be grown which include rice, maize, potatoes etc. The hydroponic systems used will be Nutrient Film Technique, Wicks system and Water culture.

Aquaponics

This method merges hydroponics with aquaculture to produce crops along with fish and other aquatic animals in one integrated system. The fish excreta are used as organic food for growing the plants and the plants in turn filter the water for fish. Red worms and nitrifying bacteria can be used to convert the waste into organic molecules. Aquatic animals like crayfish, prawns, fish and plants like cucumber, capsicum, spinach, cabbage can be cultivated in this system.

Integrated fish culture

Culturing fish along with agricultural crop is referred to as integrated fish culture. It is similar to aquaponics but in this the agricultural stock is created by soil cultivation and not hydroponics. It ensures utilization of all the resources leading to expanded output.

The waste feed from the fish acts can be used to produce manure. The crops that can grown includes paddy, maize, banana etc.

Certain species of fish like carps which are able to live in shallow water of rice and maize fields and can tolerate temperature or turbidity are cultured along with the crop.

Horticulture-fish system

Horticulture crops can also be grown in fisheries which should be dwarf type and seasonal like dwarf varieties of banana, papaya and lime. These plants are usually grown fish like carps (grass carps, common carps).

Crop variety improvement will be done by various methods like Selection, Tissue culture, Hybridisation and Recombinant DNA technology.

In addition to cultivation of plants in the agricultural level of the settlement, there will be separate fisheries located close to the settlement for culturing fish and other aquatic animals and plants. These fisheries will be associated with the preservation and utilization of various types of fish, prawns, lobsters, oysters etc. Culture Fishery will be practiced which includes rearing, managing and harvesting of fish and other animals in the water body or fishery.

Aquaculture

Aquaculture is farming and production of useful aquatic plants and animals. Organisms included in aquaculture are fish, prawns, crayfish, lobsters, shrimps, mussels, oysters and seaweeds. Aquaculture includes mariculture and algaculture.

Mariculture: This method includes cultivation of marine organisms for food in a bounded section underwater.
Algaculture: It includes farming of species of algae. The algae that are cultivated are microalgae comprising of edible phytoplankton and microphytes and macroalgae include seaweed. The problems of quality seeds and breeding can be solved by induced spawning which involves injecting fish hormones to the fish (hypophysation). Synthetic hormones viz. ovaprim, ovatide and nova will be used for induced breeding.

3.2.2 Harvesting

Agrobots will carry out harvesting after the sowing and production methods. These bots will be advanced and productive and will work full time whenever required. They will be responsible for separating the grains from chaff. Afterwards, the bots will send all the food including harvested crops and cultivated fish to the packaging and storing units.

3.2.3 Packaging

The packaging unit consists of machines and bots for the packaging of food after harvesting and culturing. Packaging must be done to prevent degradation of quality and infestation by microorganisms. The produce should be properly cleaned and the moisture content should be below 15%.

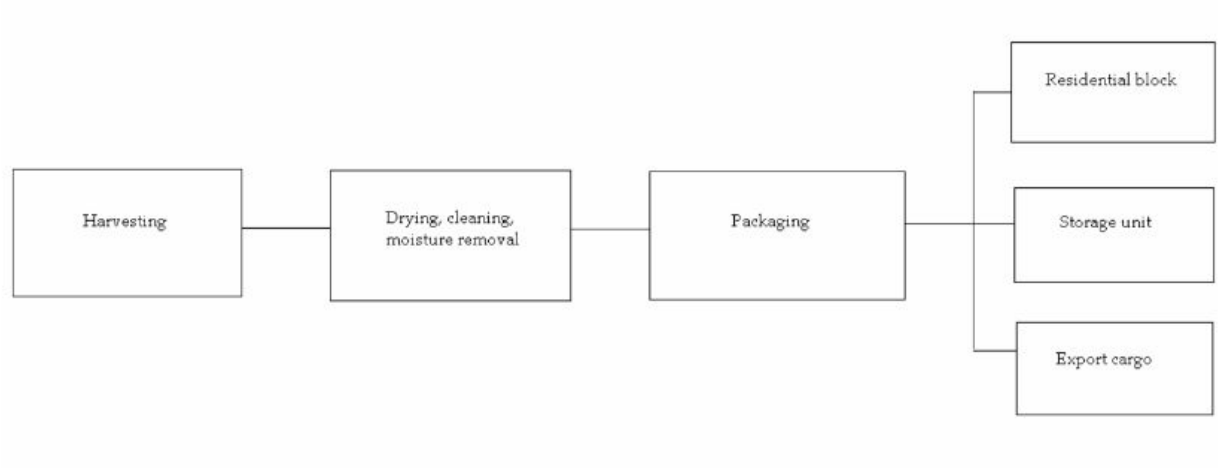
The food grains in large quantities are packed in gunny bags and other food items can be packaged in Polyolefins (polyethylene and polypropylene) which will be strong, light, flexible, moisture and chemical resistant and can also be recycled. The packets will be airtight preventing microorganism growth. Polyethylene can be used frozen food bags to store fish and other marine food and water bottles. Fish and other food products will also be stored in tin cans which are airtight and sealed. These foods are sterilized under high temperature and packed in the tin cans preventing the entering of micro-organisms. High temperatures can kill spoilage bacteria keeping the food preserved.

3.2.4 Storage

The food must be stored properly to prevent losses by various biotic and abiotic factors. The food grains and agricultural produce will be properly cleaned and dried. The produce will then be safely stored in warehouses and stores in the storage level. These stores should be cleaned and dried and have to be airtight, thermally-insulated and moisture-impervious. Pesticide solutions and fumigants can be sprayed over stored food to destroy the pests or microbes. These include BHC (Benzene hexachloride) and Malathion. Fumigants can be solid, liquid or gaseous and once applied to stored grains, form toxic fumes by reacting with the moisture of air. Methyl bromide would be largely used.

The fish and other seafood will be stored in refrigerated conditions. Before refrigeration, they will be washed in cold water and wrapped in aluminium foil or plastic wrap. Some will be packed in tin cans to prevent moisture contact. Some frozen food will also be cleaned, wrapped, sealed and frozen.

The population and bots will contribute in various agriculture techniques for producing sufficient amounts of food. The food produced will be enough for the settlement's requirements as well as transporting to the surface.



3.3 Water Management

The settlement will obtain water for its use from the water supply in the desalination system. The water will enter through the hatch and will be transported to the supply lock through pipelines. The supply lock will transport the water supply to the water management level where it will be purified and transported to the residential level and other required levels for consumption.

3.3.1 Water Consumption

Water Requirement	**Amount per Person**	**Total amount for 300**
Drinking	2-3 litres	600-900
Washing and Cleaning	8 litres	2400
Cooking	0.6 litres	180

Water will also be required for cleaning, cultivation and irrigation on the agricultural level. Amount of water for irrigation will depend on the requirement of plants and will be different for different methods. Irrigating plants and culturing aquatic organisms will require different amounts of water which will be provided to the workers and bots.

3.3.2 Purification

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The purification of water will be the most essential part of water management. The water supply will be saline which must be treated and purified to obtain potable water which can be used. Seawater purification will be done a desalination process, reverse osmosis in the desalination plant. The water will be treated by reverse osmosis and go through:
Microfiltration membranes: To avoid the clogging of the reverse osmosis membrane by solid particles like sand, suspended solids and seaweeds, Microfiltration membranes will be used to pretreat the seawater. Pore sized membranes will be used to separate the particles and contaminants. Ultrafiltration can also take place to remove even smaller particles by even smaller pore sized membranes.

Cartridge filters: These filters are made of synthetic materials coiled into cartridges. These remove smaller particles of clay and fine sand. The filtered water then proceeds to the reverse osmosis membranes.

Reverse osmosis membranes: High pressure pumps will increase the pressure of the seawater up to 1000 psi to overcome the naturally occurring osmotic pressure and force the water ahead. The salt particles in the water will be unable to pass through the membrane and get to the freshwater side. Spacers will be present in the membranes to allow water to flow across the membrane. These membranes are wound inside the vessels and enclosed in fiberglass shell. The water passes through the membranes and the salt is left behind. The desalted water will emerge at low pressure and sent to one end of the pressure vessel through a tube. The concentrated salt solution will be collected separately. The water which is purified will be converted to potable water after the reverse osmosis process.

After this process, Calcium carbonate will be added to the water to bring the pH to a neutral range. Chlorination will be finally done by adding chlorine to provide disinfection properties.

3.3.3 Distribution

The purified water will be sent to distribution pipelines which will be laid out between the cuboidal levels and the cylindrical outer protection. The water will be clean and pure for use. Water will be distributed at all times.
Processing of waste will be carried out in the Waste Processing Level where waste products will be efficiently treated. Different types of waste products will be disposed and treated separately. For this, the residential block will have separate waste disposal bins.

Organic waste

Organic waste will be stored and converted to compost by anaerobic digestion. Fertilizers and composts will be prepared by organic wastes and sent to the agricultural block. The waste can by treated by vermi-composting in separate containers. Anaerobic digestion will be done by microbial activities to form Carbon Dioxide and Methane which will be stored for various uses.

Metals and Aerosols

Metals will be sorted and crushed for recycling. The waste materials like food cans, equipment, machine parts, and wires will be crushed in a recycling machine. Aerosols will be mixed with other metals and baled and flattened in the metal recycling machine.

Plastics

Plastics can be treated by Solid Fuel Production process which involves coarse shredding and pelletization. The plastics will be processed in a crusher and then sorted. The mixture is then pelletized to produce solid fuel. Some plastics can also be converted to liquid fuel by putting the plastics in a reactor to decompose them. This will lead to formation of liquid fuel.

Glass

Glass will be treated separately by crushing and sending to recycling machine where it will be crushed and melted under high temperature.

3.5 Consumable Products

The following is a list of Consumables used and exported on a periodic basis:

Consumable	**Consumption (gram/person/day)**	**Quantity Consumed (gram/day**	**Total Quantity Exported (kg/month)**
Paddy (Rice)	150	35000	900
Maize	70	21000	420

Peas	80	24000	480
Cabbage	30	9000	180
Sugarcane	100	30000	600
Lettuce	90	27000	540
Cucumber	50	15000	300
Capsicum	45	13500	270
Pulses	150	45000	900
Microalgae	50	155000	300
Microphytes	55	16500	330
Watercress	45	13500	270
Water Chestnut	9	2700	54
Spinach	90	27000	540
Carrot	70	21000	420

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Taro	40	12000	240
Duck Potato	100	30000	600
Water Dropwort	65	19500	390
Mussel	100	30000	600
Whelk	90	27000	540
Scallop	60	18000	360
Oyster	60	18000	360
Squid	140	42000	840
Carp	100	30000	600
Cod	200	60000	1200
Crayfish	150	45000	900

Anchovy	80	32000	480
Mullet	90	27000	540

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Mackerel	70	21000	420
Sardine	200	60000	1200
Salmon	150	45000	900
Shellfish	180	54000	1080
Tuna	150	45000	900
Shrimp	110	33000	660
Lobster	90	27000	480

Apart from these consumables which will be produced on the settlement, various other consumables like technology, clothing, cosmetics etc. will be imported from land.

3.6 Deep Diving Suit

Safety plays a very important role in an underwater settlement. Protection is needed during EVA's and Repair Activities. At Anastasi, proper precautions are taken to minimize the chance of accidents. As Edward Coke put it, "Precaution is better than cure." This motto has been religiously followed while designing safety mechanisms for the settlement.

3.6.1 AMADA - EVA Suit

The suit will look similar to the Exosuit design of NUYTCO. Image from The Verge.

Expeditions outside the settlement will be very dangerous considering the high pressure and dark environment. Inhabitants on EVA will have automations to help them in their operations to make manual work in the sea minimal but is inevitable that humans will have to go out in the sea. The humans will require a layer of defense against the pressure apart from the needed oxygen and insulation. Temperatures in the Dead Sea are not very extreme ranging from 10 degree Celsius in winters to 25 degree celsius in summers in the deeper waters (Around 250m depth). In the shallower waters (around 25m depth) the temperatures are higher ranging from 15 degree Celsius in winters to 35 degree Celsius in summers. *[Gertman and Hecht, 2002]*. Therefore, not much heating will be required. For EVA operations, a special diving suit known as AMADA (Atmospheric Magnesium Alloy Diving Armor) will protect Anastasi explorers from the harsh conditions in the sea. Not only this, AMADA is also well equipped for emergency situations and the human inside can survive for 5 days till rescue operations save him/her. Using a non-atmospheric pressure suit would need saturation diving mechanisms which require a very long pre-breathing period up to 10 hours to remove nitrogen from the body. This would make the process very long and tiresome. An alternative was making the entire settlement equal to the outside pressure but because

of the huge pressure difference on different depths of the sea, this would again cause problems. An atmospheric diving suit provides atmospheric pressure at all depths and allows the settlement pressure to be atmospheric too thus making operations easier between the surface as well as during EVA.

3.6.1.1 Materials

AMADA is an Atmospheric Diving Suit specially designed for Anastasi expeditions. It will have an inflated heavy outer body made of Magnesium Alloy to protect against pressures up to 50 atm inside the sea. The pressure in the deepest parts around Anastasi where divers can be calculated using the depth. The maximum depth at which humans will be required to work will be 280m (when the submarine oil rig is in deeper parts). In normal oceans, every 10m corresponds to 1atm increase in pressure. However due to high salinity in the dead sea, every 10m will mean 1.3 atm increase in pressure. *[Michael Braunstein, 2013]*. Therefore maximum pressure conditions will be approximately 28*1.3 = 36.4 atm. AMADA can easily handle this pressure. The following is a trade study to show why Magnesium Alloy was chosen for the outer covering. It is important to note that all the below given materials have enough strength for combating pressure and therefore strength has not been taken as a factor.

Material	**Cost/Availability**	**Reaction to Water**	**Weight**	**Total**
Magnesium alloy	9	8	8	25
Aluminium alloy	8	8	7	23
Fiberglass	7	8	7	22
Carbon Fibres	5	8	10	23
Steel alloy	9	4	4	17

It can be clearly seen that magnesium alloy is best suited as magnesium is abundant in the dead sea and can be obtained from the desalination process. Steel is also a cheap generally available alloy. Aluminium alloy has a similar cost to magnesium alloy however it will not be produced on the settlement and hence a lower score has been given. Fiberglass is more expensive and not made on the settlement, hence a lower score than aluminium has been given. Carbon fibres are much more expensive leading to the very low score of 5.

Magnesium does not react with saltwater in normal conditions thus making it perfect for the outer covering shell of AMADA. The same can be said for all the above materials except Steel Alloy which corrodes easily leading to the low score. Magnesium has a low density of 1.74g/cm^3 and this reduces the weight of the bulky atmospheric suit. Aluminium alloy and fiberglass have a higher weight leading to the lower score. Carbon fibres are very light which is why they have been given a perfect score. Steel alloy is much heavier leading to the low score.

Magnesium Alloy will be used as an outer covering in the whole suit except the helmet. This is because transparency is needed for the helmet. The helmet will be made of more expensive Transparent Alumina which itself is as strong as Magnesium Alloy but is transparent and clear. A waterproof coating will be added to this to ensure that vision is not hampered.

The next level of protection will be of cheaper, flexible and weaker polypropylene which will act as a secondary protection layer in case of damage to the outer magnesium alloy shell. The polypropylene will easily hold the pressure for long enough to allow the diver to return to the settlement for repairs. Polypropylene will directly act as an inner padding so that the human inside AMADA does not have to feel the metal outside and also acts as an injury prevention layer from the hard metal. The human inside AMADA can wear any thin clothing layer as a covering for his body. This will include gloves on the hand for sanitation reasons and soft shoes.

3.6.1.2 Life Support of AMADA

The Life Support System is attached on the back of AMADA. It consists of:-

1. **Power Module**: This module contains power batteries that have enough power for 1 day of normal function and upto 5 days of functioning in Power saver mode. This power is transferred through internal wiring between the magnesium shell and polypropylene layer as polypropylene is an insulator and can act as a layer of protection in case of malfunctions.
2. **Oxygen Module**: It consists of compressed stored oxygen that can last 5 days and is released inside the main AMADA body through tubes.Artificial gill designs like the “Triton Gill” will not be used due to the sheer cost of producing them and as they are unreliable.
3. **Carbon Dioxide release**: Carbon dioxide exhaled by humans is separated and transferred to the Life Support System. Small tubes release carbon dioxide into the sea periodically by building up pressure in the tube higher than that of water

and opening to the sea, due to higher pressure carbon dioxide flows out and water does not enter. As soon as the carbon dioxide escapes, the tube is shut and build up of carbon dioxide begins again.

4. **Waste Management**: The Waste Management module stores urine and separates water for use. The toxic wastes of urine are stored and taken to the settlement. Solid wastes are compressed and stored in a small pocket that can store wastes generated over 4-5 days.
5. **Water Module**: This module will store water and refill reserves from water separated from urine. The initial storage will be worth just 1 day however refills from urine will make it last for 3-4 days. In emergencies when the diver can't return for so long, sea water will be taken in small amounts and minor desalination will be done to make the water just fit for survival. Full blown desalination will require energy which in itself will be scarce in the last day or two in the 5 day period. Water will be sent to the helmet through tubes and can be sucked from the pipe.
6. **Food Module**: Food will not be needed during normal operations. However a food tonic supply will be maintained in case of emergencies. These tonics will be taken once every day and will satisfy hunger as well as provide nutrients. Their reserve will also last 5 days.

The Human inside AMADA has some basic control over life support operations and can overrule or change certain mechanisms if needed.

3.6.1.3 Helmet

The helmet will not only provide survival and visibility functions, it will be technologically advanced and make all operations quicker. The helmet will include hologram technology and air swipe controls so that the diver can monitor various screens and give various commands simultaneously. These will not appear on the visor as this can lead to complications in sight. Instead, they will appear a little above the line of sight and the human inside will have to look up a little to monitor them. The visor will show atmospheric conditions around the user, possible dangers nearby like rocks and also allow the user to use different tools like camera, gps, heart-rate monitor etc. Voice commands will be used in "Pirate - Code" which is a strict army like system of speech. *[Idea from Freyr Project, Ames Grand 2015]* This has been done as general speech may include many difficult to identify slangs and similar words that can cause confusion. When the voice detectors look for limited, well differentiated words, it becomes easier for them to process commands. Examples of Commands include "Ahoy, Captain!" To turn on a system and "Avast, Bilge Rat!" To shut it. Microphones and Speakers allow communication from the base as well as between divers. Music that humans like help

them to concentrate on work better and improve their effectiveness *[R. W. Wilkes, 2014*]. Therefore, Music will be allowed according to predefined soundtracks by the user. Whenever communication from the base or other divers comes, the music will be paused and the communication relayed.
The helmet will also have basic life support functions like the food and water tubes, carbon dioxide drainers, oxygen inflow systems etc. Even though the helmet will be donned separately, it will become completely connected with the overall AMADA body after it is worn. The helmet will also have a powerful LED light making areas within a 30m radius visible. A small SONAR system will be attached fully equipped with transmitter, detector and interpreting computers to map out obstacles. This SONAR system will have its own small power backup which will be used to send pings after every 15 minutes to the detectors on the settlement during emergencies to assist rescue operations. The helmet will thus inculcate both safety and ease of use attributes.

3.6.1.4 Navigation & Mobility

AMADA being a 150kg-200kg (based on dimensions of user) suit will cause some problems in navigation. Since the overall density of AMADA (ranging from 1.4-1.5 g/cm^3) will be a little more than that of the saline water in the Dead Sea (1.2-1.4 g/cm^3), Divers will naturally sink. This doesn't happen with the normal human body (0.99-1.05 g/cm^3) in the dead sea. This is actually good as divers will not be brought naturally to the surface. A series of Rotary joints in the parts of the suit will allow flexibility & movement. *[Nuytco Research, 2014*]. Normal human movements inside AMADA will be thus mimicked at a slower rate.

Thrusters which store and release a 90% hydrogen peroxide solution will be used for generating thrust. 16 such thrusters around the body will be used to change directions and move around at varying speeds. The hydrogen peroxide will be released at a high pressure and the thrusters will close and open rapidly releasing a hydrogen peroxide bust whenever they open.

A huge structure like AMADA may seem very difficult to navigate but it can move at speeds up to 10km/hr and is easy to control. Navigation will be done using hand movements and thruster speed will be managed through voice commands.

3.6.1.5 Doffing/Donning

The doffing/donning zone is where the diver will wear the AMADA suit and other additional modules. Carbon Fibre arms will be provided if asked for in the information Panel. The donning mechanism requires the diver to stand on a platform on which the

lower half (legs) of the suit is present. Next, the diver wears the torso part normally like any t-shirt (though it is heavy and difficult to wear). After this, robotic arms fix the upper leg or thigh part of the suit. The diver also wears the arm parts by putting his hands through the Carbon Fibre/Magnesium Alloy arms held by robotic arms. All these parts are then joined and sealed by carbon nanotube linings that ensure they do not get separated even under immense pressure. Next the helmet is fixed by the robotic arms. If any discomfort is noticed due to robotic malfunction, the diver can immediately stop the process and inform the headquarters. After this, the suits power turns on. Donning usually takes 15 minutes.

The whole process gets reversed while doffing. The power is switched off once on the platform. First the helmet is removed by robotic arms. Next, the carbon nanotube sealing is slowly dismantled by loosening it. After this the hands are freed and the thigh parts removed. Then the diver can manually come out of the suit.

The platform begins at a normal height but once the diver steps on it, on his command it rises upwards towards the robotic arms to a height of 1m. This is done so that climbing on the platform is not required.

3.6.1.6 Cost and Production

AMADA will be produced on land by hiring contractors who will work on providing different parts according to the proposed design. The suits will have to be tailored to fit different users but it will be ensured that designs are easy to tweak and re-usable.

AMADA is not a cheap design as state of the art technology and safety measures have been taken. It will be used by a total of 38 people who have EVA operations. This does not include the Sunlight Capturing mechanism repair population who will be using normal Wet Diving Suits as their operations do not take place in deep high pressure areas. These 38 people will be well divided into 2 shifts with 19 workers each. 25 AMADA suits will be kept on Anastasi to keep an emergency buffer stock in case of damage while also ensuring that costs are minimized.

The following is a cost breakup of a single AMADA unit:-

Part	**Sub-Heads**	**Cost (In USD)**
OuterShell	125 kg (avg) Magnesium Alloy	2000
	Interface between parts	1000

	Paint and Coating	500
	Overheads	400
Inner Interface	10kg PolyPropylene	200
	Lighting & Support	250
	Overheads	200
Helmet	2kg Transparent Alumina	1500
	AI & Technology	5000
	SONAR & Light	2500
	Overheads	300
Life Support	Internal Wiring, Tube Systems	5000
	Power Module	1000
	Oxygen Module	500
	CO2 Module	500
	Waste Management	750
	Water Module	500
	Food Module	500
	Covering	300
	Overheads	400
Navigation & Mobility	Rotary Joints	1500
	16 Thrusters	2000
	Motion Imitation Mechanisms	2000
	Overheads	500

R&D	Research	5000
	Testing	2000
	Assembly	2500
	Contractor Payment	5000
	Overheads	1000
Total	**Total**	**43,300**

AMADA will take a total of USD 43,300 for production of a single unit. This is excluding consumable costs like the hydrogen peroxide, batteries etc. It is estimated that daily costs of running a single AMADA unit will be around USD 100. **Therefore 25 AMADA modules will cost USD 1,082,500 with a daily expenditure of approx. USD 200.**
An important feature of AMADA is its similarity to spacesuits. It can thus be used as a cheaper and safer alternative to realistic spacesuit EVA training.

3.6.2 Recreation Diving equipment

A separate skin-tight diving suit will be used for recreation activities. These activities will take part in shallow areas and will not require the hard-shell protection of the AMADA suit. The skin-tight suit will provide mobility to the
The divers will require proper equipment for their safety, movement and for handling hyperbaric conditions. The equipment for carrying out recreation EVA's includes:

- Twin cylinders with hose regulator or aluminium scuba cylinder, decompression cylinders, closed circuit rebreather sets will serve as breathing apparatus mounted by the person.
- Buoyancy Control Device (BCD) or stabilizer consisting of an inflatable bladder to produce neutral buoyancy underwater.
- Wet suit made of neoprene will be available for moderate water temperature zones. It will be used when temperature is around 25°C which will require Dive skins made of Lycra.
- Diving gloves and hoods will be worn with the suit.
- Safety helmet with forehead light or flashlights.
- Full face mask protects the face and provides gas supply and allows clear visibility.

- Diving weight belts will counteract buoyancy of the diving equipment for descent and stability underwater.
- Swim fins made of rubber will allow movement and propulsion
- Depth gauge indicates and monitors depth.
- Dive computer or diving watch indicates decompression stops and depth.
- Submersible pressure gauge keeps track of the gas supply in cylinders.
- Diver's safety harness or tethers for the safety of the diver.
- DiverGuard or Divo is used to inflate the BCD if the diver is unable to breathe. It may consist of an alarm to inform the safety unit in the settlement.

Before going on an EVA, the diver must wear the wetsuit or the Dive skin for buoyancy, protection and thermal insulation. The Dive skin can also be worn under a wetsuit which allows easier donning and provides comfort. The cylinder is mounted by the diver which acts as an air source containing the gas supply for breathing. The full face mask is worn which provides the gas to the diver. Diving gloves and hoods are worn and fins are donned. The fins enable easy movement and propulsion inside water. Safety helmet is put on for protection which has flashlights for visibility. Reclaim helmets can also be taken which will supply the gases to the divers and send the exhaled gas to the return line for recovery of the gas. Diving weight belts acts as ballast and counteracts buoyancy of diving suits and cylinders. Buoyancy Control Device is back mounted and is used for controlling buoyancy by adjusting the volume of air and is a part of the harness system. Sometimes, Diver Propulsion Vehicle (DPV) is used to increase the range of the diver. The depth gauge helps in navigation and monitoring depth and ascent rate. Dive Computer or Diving watch is put on to monitor decompression. Handheld sonar can also be taken for survey and exploration inside water which acts as a range finder. Surface marker buoy can be taken by divers going deep to mark their positions for safety. Additional equipment like spearguns, nitrox cylinders will be available for recreational activities.

3.7 Saturation System and Airlock

3.7.1 Hyperbaric medical aspects

Working and staying in hyperbaric conditions can prove fatal to one's health and can lead to many disorders.

Decompression sickness is a condition caused by bubbles of inert gas which gets dissolved in the body tissue, decompressing them which may lead to blocking of blood vessels. It is can be very fatal as it leads to pressure reduction while ascent. Limiting the

rate of ascent and regular pauses can allow the pressure of gases in the body to approach equilibrium and prevent Decompression sickness.

Dysbaric osteonecrosis is when nitrogen embolism leads to blocked blood vessels and damage to a part of a bone. It can be prevented by minimizing the number of decompression exposures and using HBOT (Hyperbaric Oxygen Therapy) which will be provided to the divers suffering in the health centres present in the residential level.

High-pressure nervous syndrome (HPNS) is rare as it only occurs in great depths by breathing a helium-oxygen mixture. Avoiding depths and high pressure areas and adding a small amount of nitrogen to the mixture of helium and oxygen can prevent HPNS.

3.7.2 The Saturation System

The saturation system consists of pressure vessels attached to the human exit level. The system will be present for inhabitants going on EVA's and saturation divers. This would reduce the risk of decompression sickness for those who work underwater for long durations of time. The system comprises of a transfer chamber, recompression chamber, supply lock and transfer capsule.

The persons will go to the transfer chamber from the residential block where donning and doffing occurs. The chamber includes sanitation facilities for the diver. The diver cleans himself and his equipment before going back to the residential area.

From the transfer chamber, the diver goes to the transfer capsule with his gear when he is ready for diving. The transfer capsule is a spherical shaped pressure vessel having hatches at the top and the bottom. The diver enters through the top hatch and enters the transfer capsule. The bottom hatch opens for the diver to go by himself with his equipment.

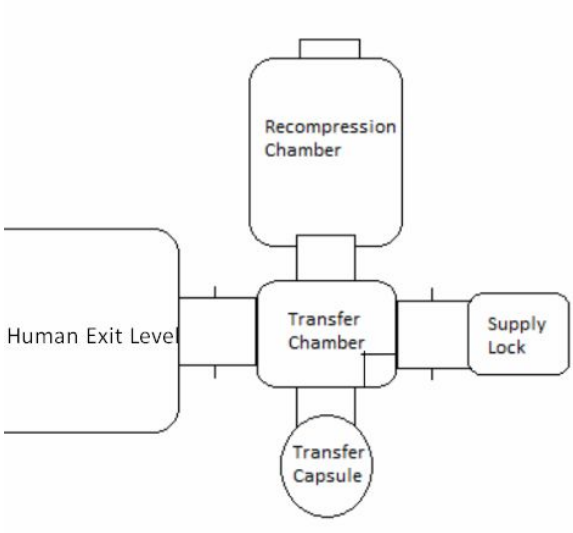
The Recompression chamber is very important as it treats the divers having decompression sickness. The diver is immediately brought to the recompression chamber through the transfer capsule when he contacts the control crew.

The diver is treated by recompression if he is suffering from decompression sickness, Dysbaric osteonecrosis or any other depth effect. If the situation worsens, he is sent to the health centre of the residential block to diagnose the body and provide treatment. The person can be given HBOT in case of requirement.

Airlock: The transfer chamber will have an opening in the corner to allow water into the supply lock through a moon pool. This will maintain the ambient pressure inside the supply lock. The transfer chamber will serve as an airlock for maintaining hydrostatic equilibrium and adjust the pressure between the ambient pressure and atmospheric pressure in the main residential block. The airlock will allow entry and exit from air environment in the pressure vessel and the water environment outside. The pressure will be regulated in between to balance the pressure and avoiding sudden pressure change. The airlock will control the pressure of the water as around 20 atm and pressurize the transfer chamber to a pressure between the ambient and the atmospheric pressure before the inhabitant enters the main block. The diver might have to wait inside the transfer chamber (airlock) in accordance with decompression tables and may have to the recompression chamber.

Supply lock holds the diver's supply and equipment and can be used to store it when he returns. It is used to transfer the supplies from the residential block to the system and vice versa.

Rescue and escape chambers are provided with the systems which can be attached to the transfer chamber hatch for the person to be evacuated. The diver can escape hyperbaric conditions in these chambers which have proper life support system and emergency supplies. The chamber will provide protection to the occupant.



(The Exit hatch)

3.8 Frequent Cargo Mechanisms

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Apart from oceanic transport vehicles, which will be used for transporting people and large amounts of sensitive cargo like machines and electronics 2 times a week between land and the settlement, mechanisms to transport cargo faster will be set up. These mechanisms will be mainly used for transport of Anastasi produce ranging from wastes and pollutants to products like Deuterium, Salt, Crops etc.

3.8.1 Salt Belt

A salt conveyor belt will be setup for regularly transporting salt from the settlement to land. This belt will operate at a depth of 130m from the desalination area covered by a magnesium alloy body. This 3.25km long conveyor belt made of 7 km long material will operate at a speed of 10 complete cycles per hour and will run constantly powered by the oil energy. This will be sufficient to transport the 3600 tonnes of salt generated every hour. The conveyor belt will operate 23 hrs a day and the remaining one hour will be utilized for maintenance activities. The cost of constructing this conveyor belt at $5000 per ft. is $120,000,000. This will be a one-way transport system. This conveyor belt cannot be used for any other cargo as a separate section would have to be built leading to unnecessary costs. The same salt section cannot be used as it would lead to pollution of the salt and the salt can also corrode and rust the cargo delivery boxes. The below described systems are much cheaper as other cargo will not be transported in such huge quantities as salt.

3.8.2 Boats

Five motor boats with capacities of 1000 kg transports or 1mx1mx1m dimensioned objects will run hourly between land and Anastasi during the Joran day. These will be used to transport Deuterium boxes, Waste Boxes, Crops (in harvest periods) etc. Material will be transported to these boats by sending the material to the Water and Food level in tightly sealed boxes and then this material will be dropped in the sea to float up in Buoyancy Bubbles. These bubbles will be made of Polypropylene which will be able to withstand a maximum of 20 atm which is more than the maximum they will have to face. These bubbles will surface on land and the people on the boats will take the material by deflating the balloons. They will then send these back to the settlement using the ERL described below. The dead sea water is largely calm and thus these bubbles will not deviate much from their paths.

Ships or bigger transport vehicles have not been used as these are costly and difficult to maintain. The larger capacity is not needed and Constant boat supply can easily transport the materials. These boats will be hired on a monthly basis with salaries for the owners ranging from $5,000 per boat per month to $10,000.

3.8.3 Export Receival Lift (ERL)

Export from land brought through boats will be sent to the settlement using an Export Receival Lift. This lift directly connects to the Storage Level. The lift comes out of the water surface and allows transport boat sailors to drop the transport in the lift. This can be done only when the cargo clears a security check. The maximum size of cargo that can fit in is 3mx3mx5m. The cargo then comes down on platforms till it reaches a conveyor belt at the depth of the Storage level perpendicular to the settlement. The small conveyor belt then transports this material to the storage level where further processing occurs. The construction of the ERL will cost $1,000,000.

3.8.4 Oil Transfer Mechanisms

Oil mined at the submarine oil rig needs to be transported to the settlement constantly to ensure power supply and raw material for refining. The submarine oil rig will have a storage where mined crude oil will be stored. 10 unmanned oil ships each with a capacity of 10 kilo litres will move to and fro between the oil rig and the vehicle level from where their supply will be taken and sent to the oil refining level. These oil ships will be regularly maintained and will complete one round trip from the rig to the settlement, emptying their supply and back to the rig in 2 hrs. This allows for a capacity of 12 runs by 10 ships in a day meaning a 120 kilo litre capacity. This is much more than the expected 25kilo-litre daily supply produced by the rig. This keeps an allowance for future expansion and also will not cause problems in supply in case of failures of some ships. It will also mean that not all ships will have to be filled to their full capacity making them lighter and less prone to damage. Each oil transfer ship will cost $100,000 leading to a total cost of $1,000,000.

3.8.5 Buoys

Buoys can be used for carrying the goods by attaching one to every load. For this, special mooring buoys will be used to transport the bulk cargo which will be sent from the surface frequently. The buoy will be affixed to the freight containers having packed food supplies of moderate weight. The buoy should be big enough for carrying the weight to be floated to the surface. The mooring buoy should of the size to displace the same amount of water as the weight of the load. Extra buoys will be available at the settlement for extra or emergency supplies. The buoy will travel through the terminal so that it reaches the surface base directly. There, it will be hoisted along with the goods which will be detached. The buoy will then again be sent underwater for getting more supplies. These mooring buoys will be functional and convenient for transporting as

they can easily carry the cargo and the containers can be lifted one by one. Different weights can be conducted using different sized buoys as they will be able to displace the water accordingly making the goods float to surface. They can move through the terminal without difficulty. The buoys can be used repeatedly after unloading and hence easily supply the cargo frequently.

These mechanisms allow frequent transport of smaller less sensitive cargo and products in a cheaper fashion.

4 Human Factors

4.1 Community Design

The residential level on Anastasi has been divided into 5 separate levels. There is a 1 m separation between each level for complete division. Each level has a down surface area of 100mx100m = 10000m^2 and a vertical height of 9m (excluding separation). The first two levels host the residential areas, parks and other commodities for those working during day hours as in Jordan. The bottom two levels host the same for those working during night hours as in Jordan. The day/night cycle will be completely opposite between these levels so that residents always feel that they are working in the day. The central level will host the offices and public facilities. These include the control rooms for various EVA activities. This level will not have a night time and will be lighted all the time though the hue of the light will become darker during each shift and will become light again when shifts change. All this will be done to ensure realistic life as on land. A single 50m long storey with high rise buildings could have been an alternative to this multi-level design however the dimensions of the residential sector would have to be increased in this case not only increasing costs but also the stability of the overall settlement. The multi level design multiples the down surface area available by 5 times while ensuring that the residents do not feel claustrophobic by providing a 4m gap between the tallest part where the human can visit and the ceiling.

The four residential levels will have a symmetrical design each having 55 single person houses and 10 dual-houses. Each level will also have a small chemist, ice cream parlour, food zone, shopping complex, law enforcement office, gym, worship areas and central park.

The central level will have offices for the External Repair team, the General Security and Automation team and the Administration and Management team. This level will also have a public health centre and a community hall with a seating capacity of 400 (extra in case of future development). There will be a dedicated recreation zone with a variety of recreation activities. The health center will deal with minor health issues and provide medication. A diagnostic lab will be a part of the center which will be well equipped with machinery for proper diagnosis and treatment. The health center will be specialized in dealing with underwater health problems and pressure hazards. Fatal conditions like decompression sickness, high pressure nervous syndrome and other depth effects will be diagnosed quickly by the bots and machinery and produce a scan. The person will

then be operated and in extreme conditions, sent back to the surface. Hyperbaric Oxygen Therapy (HBOT) can be used for treating many health disorders.

All levels will have separate bicycle tracks and footpaths. No vehicles other than bicycles will be present on the settlement as the distances are very short. Public bicycle zones will be setup on each level and people will not have to own a bicycle.
The community ensures that people get as close to land environments as possible. Plants and Trees as seen on general roads of cities will be provided on each level. The overall environment will be peaceful and pleasant.

4.2 Residential Design

There will be three types of residences on the main Anastasi Settlement. These are the Single Person Apartments (Total 120), Family Houses (Total 25) and the Dual Person Bungalows (Total 40). All 3 will make use of Foldable Furniture made of Strong Plastic and Weather Control Systems and will have a terrace. They will be surrounded by greenery to give a comfortable feel.

4.2.1 Single Person Apartment - 225 sq. ft

2D View

3D Views (L-Kitchen/Entertainment R-Bathroom/Bedroom/Kitchen)

The single person house is a small apartment 15ftx15ft apartment. The resident will also have the terrace available for pass-time activities like gardening. The house will have foldable furniture so that space can be saved. Doors will be present on corners of rooms to save space. Each house will have a single bedroom, bathroom, a kitchen, a combined drawing/dining and a workstation/storage room. The bedroom will be equipped with a projector TV which can be used for an enhanced gaming experience as well. The kitchen will have a bio-refrigerator made of a gel cooling system, microwave and dishwasher. It will not have any stove as cooking will not take place and food will be taken from the food zone. The entertainment(drawing/dining) room will be equipped for guests as well. It will also have a Virtual Reality Zone which is a small area powered by Virtual Reality technology with gaming options, relaxing scenery options etc. The workstation and storage is basically like a free area where the resident can store his belongings. The bathroom too will be well furnished with attached Music Speakers for a rock n roll bath. While entering the house, security checks will be done and it will be ensured that dirt is not brought inside. The walls have air conditioners which can be controlled from the storage and work-station and keep the house ventilated. The simple 5 room design cuts costs & efforts which are needed to maintain complex designs.

4.2.2 Dual Person Bungalow

The dual person bungalow will be provided for couples and workers who want to share their houses and have some company. These living quarters will ensure minimal wastage of space and yet will allow a comfortable lifestyle. The dimensions of this house will be

25 ft x 15 ft.

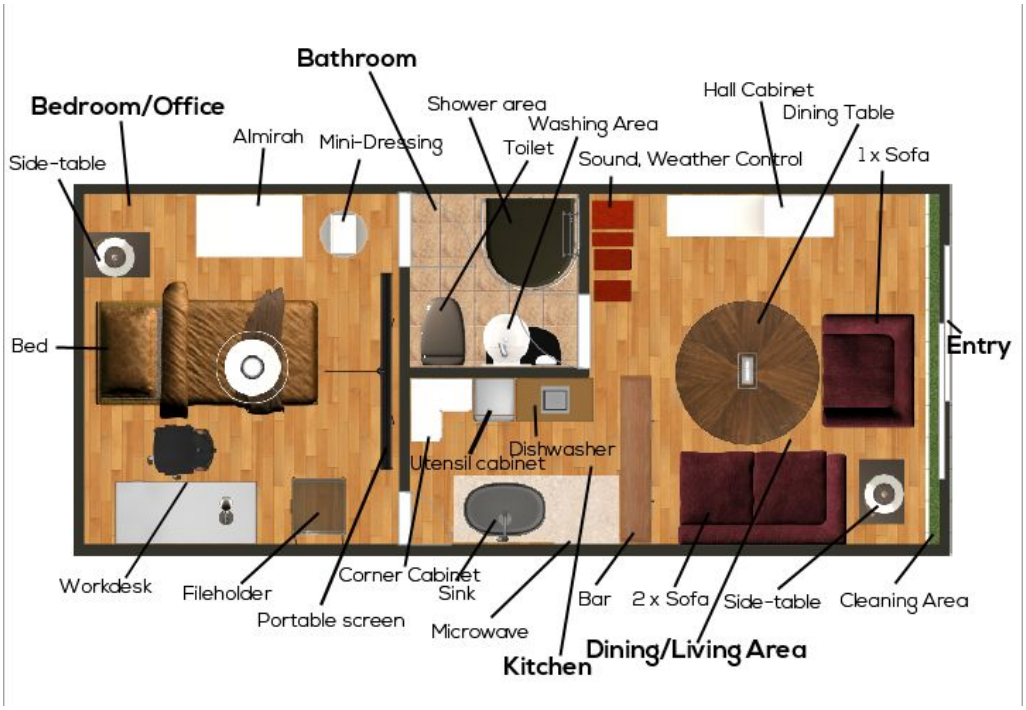


**Diagram to Scale. 2d model of residence interior.*

- The above images show the interior design of the bungalow. The thick white lines show doors whereas the thick black lines indicate walls. The doors have been made in the corners of the rooms to ensure that space is not wasted when these doors are opened. The walls have air conditioners which can be controlled from the central unit in the living/dining area and keep the house ventilated.
- On entering the house from the sliding door, a cleaning area, matted with artificial grass comes. In this area, the user stands for 5-10 seconds as a quick scan ensures that dirt is not being taken inside the house. The area can also be used to stroll as fresh air jets and artificial grass give a lawn like feeling.
- After this, the user comes to a combined living room, dining room & hall. This has a seating space for a maximum of four people at a time on the table and is combined to reduce wastage of space. Sound, climate and other artificial intelligence can be controlled her through the main control body which is designed to look like a stereo, however it does much more than that. This area has 2 cabinets, the hall cabinet which can be used to keep decorations, pictures and other objects and it also has a wall unit that can serve the purpose of a bar.

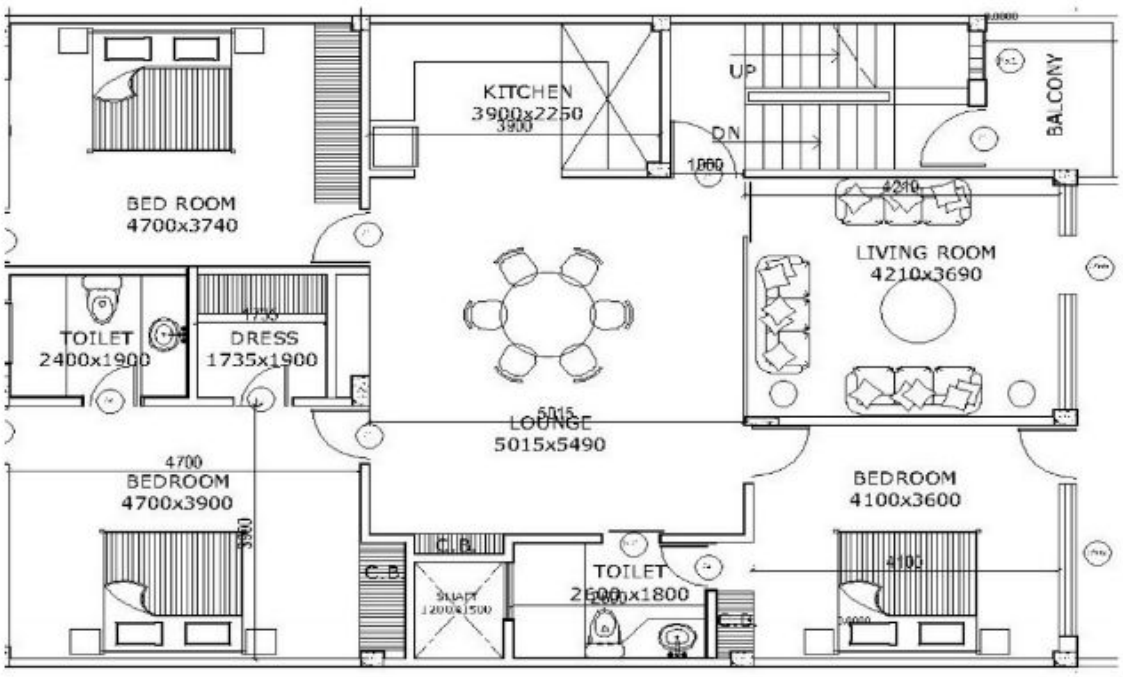
The Virtual Reality zone can be kept here.

- The kitchen is directly attached to the living/dining area & the bedroom and its central location makes it easy to heat food here and eat it elsewhere. It is equipped with a dishwasher, a bio-refrigerator, some cabinets to keep utensils and other quick snacks in and a microwave to heat eatables brought from the food zone.
- The bathroom is attached to the living/dining area as well as the bedroom and its central location means that guests as well as the resident can use it. and consists of a shower area that is specially designed to recycle water. the water does not come out from this shower area and keeps getting cleaned and reused.
- The bedroom has an integrated office-like workstation with a file holder and a desk so that the resident can work at home if needed. An almirah, side-table, bed and a mini-dressing complete the bedroom. The bedroom is where the television screen will be kept.

The overall design of the house has been smartly ordered so that visitors do not get to see the bedroom which is a private area. Visitors mainly have work in the lobby which in this design is served by the living/dining area. The utility areas like the kitchen and the bathroom are central so as to provide supplies to both the bedroom as well as the living/drawing areas. Minimum use of walls has been done as constructing walls takes space and is also costly.

4.2.3 Family House

The residents of family houses will live in linked houses which will be connected and there will be a green area in the centre. The residences will serve as commodious dwellings.



Linked houses will be present as rows of cognate houses sharing same side walls. These will be linked and therefore build a main community for the people to live jointly.

4.2.4 Exterior Design of Houses

All houses will look similar from the exterior. Each building will have 3 storeys:

(*Made using Dreamplan 3D)*

4.3 Recreation

Recreation is necessary for every human to ensure proper functioning of the brain. Recreation facilities have been provided in Anastasi keeping in mind that a healthy body is the home for a healthy mind.

4.3.1 Home Recreation

Residents are expected to spend maximum time in homes. Considering this, special recreation facilities have been provided in houses. These include:

1. Smart 3D HD Television with an attached Gaming Console and Digital Library.
2. Virtual Reality Zone, a small 3ftx3ft closed area where divers can enjoy Virtual Reality games, shows, climates etc.

3. Sound, Climate, Scenery controls in the houses which let the diver enjoy varying conditions of various parts of the world while at his home.
4. A terrace where gardening can be practised and sports activities can take place.

4.3.2 Outdoor Recreation

Recreation activities have been set up by building special infrastructure for them. These include:

1. Central Park in all sub-levels of the residential level.
2. Gyms with modern technologies in all sub-levels of the residential level.
3. Community hall in the Central sub-level
4. Restaurants, Cinema, Indoor Aquariums, Gaming Parlours, Ice-cream parlours etc. in the Recreational zone of the Central sub-level.
5. Water-view hall in the recreation zone (a small part of the wall will be made of Transparent Alumina to allow views).
6. Activities offered in the Tourism Area can be availed for free by the crew from time to time.

4.3.3 Underwater Recreation

Proper scuba equipment will be given for underwater diving, spearfishing and various water sports as mentioned in section 3.6.2. The following recreation activities will be available to the crew:

4.3.3.1 Recreational diving

Recreational diving includes many diving activities for merriment and leisure. The divers are to be provided with diving suits and equipment and be trained before indulging to avoid risks. This includes activities like cave diving, freediving, snorkeling and nitrox diving.

Cave diving is a type of technical diving in underwater caves. Divers can venture and look for caves for exploration purposes. These places will be inviting but this activity can be perilous so the divers must be provided with safety systems.

Free diving will be practiced near the surface where the diver should have the capacity to hold their breath underwater before resurfacing. The divers require less equipment in free diving and health hazards are prevented. It is an easy style for everyone to try.

Snorkeling is a popular recreational activity for discovering and exploring the underwater life. It requires a snorkel which is a shaped tube and less equipment. Snorkeling is used in underwater sports as well.

Nitrox diving will be a special attraction and will involve a training program. It will use nitrox diving tanks which will be a gas mixture of nitrogen and oxygen. It reduces the proportion of oxygen in breathing gas mixture and will decrease the risk of decompression sickness by increasing the proportion of oxygen. It will reduce the pressure risks and lengthen the underwater diving interval.

4.3.3.2 Underwater sports

Finswimming is an underwater sport which uses fins and snorkel. It includes various techniques and can be practiced as a competition.

Free diving and sport diving are also sports that use recreational open circuit scuba diving apparatus and are practiced near the surface.

Spearfishing is an interesting method of fishing with slings and spearguns to hunt and catch fish by proper targeting and focus. This can require the diver to go deep underwater like in Blue water hunting to look for large fish species.

Underwater target shooting helps the people to learn how to use a speargun for targeting and shooting underwater. This requires skill and control. This can be practised by people before starting spearfishing which is widely enjoyed.

Other sports include underwater football, underwater hockey and underwater rugby involving two teams. The teams score goals by sending a negatively buoyant ball into the goal.

4.3.3.3 Underwater photography

The divers go deep inside water to take photographs of underwater views and aquatic life. The geology, marine flora and fauna, cave systems offer great photographic options. The panoramic views can be captured by nature and photography lovers. The equipment includes waterproof cameras. It includes underwater videography and recording as well.

These will provide for good breaks from regular day to day lives of the crew.

5 Business

5.1 Business Plans

It can be said that Anastasi is a work based settlement. Anastasi has detailed business models and plans to show its capacity to earn profits while improving the environment of the Dead Sea. The following section provides a detailed cost recovery and expenditure breakup because *“An investment in knowledge pays the best interest.” - Benjamin Franklin*

Anastasi’s costs will be primarily recovered through a variety of business plans. The infrastructure for the setup will require a heavy investment. Costs will be recovered mainly through the following heads:-

1. **Deuterium Sale**
2. **Crude Oil & Refined Products Sale**
3. **Underwater Research**
4. **Salt & Minerals Sale**
5. **Tourism Activities**
6. **Sale of Agricultural Products**
7. **Space Training**

5.1.1 Deuterium Production

Deuterium is an isotope of hydrogen which has heavy demand in the Fusion Industry which is now globally identified as a Sunrise Industry. Deuterium mining is a safe investment for the future as Chinese, American, Russian & Indian projects to the moon for Helium-3 mining are already close to launch. Deuterium is already an important commodity as it is rare on earth and has applications in Tritium Fusion, Deuterium - Deuterium Fusion as well as Helium-3 fusion.

“I looked for it because I thought it should exist. I didn't know it would have industrial applications or be the basis for the most powerful weapon ever known [the nuclear bomb] … I thought maybe my discovery might have the practical value of, say, neon in neon signs.” - Harold Urey, Won the Nobel Prize in Chemistry in 1931 for discovering Deuterium.

Deuterium will be sold primarily to aerospace companies to promote the growth of fusion propulsion thus making space transport cheaper and faster.

5.1.1.1 Production Quantities

Deuterium is currently evaluated at over $7000 per kg according to international standards. However there are a couple of projects for deuterium production under construction which will bring down the price to $5000 per kg by 2050. $5000 will be used for business calculations. Deuterium is found in 1 out of every 6420 atoms of Hydrogen. Around the settlement, the concentration is expected to be around 1 per 3000 hydrogen atoms due to the fact that the Dead Sea is an Endorheic basin. This could have been as high as 1 per 2000 in deeper parts of the Dead Sea however they weren't chosen due to factors mentioned earlier (Refer to 1.4). This means that to obtain 1 kg of Deuterium, 3000 kg of Hydrogen will have to be processed. Water having a ratio of 1:8 between Hydrogen and Oxygen, 27000 kg of Water will have to be processed to obtain 1 kg of Deuterium. This is also equal to 27000 litres of water. The mining process is not that accurate however and will need to process 32,000 litres of water to obtain 1 kg of Deuterium. The Deuterium Mining infrastructure will have an initial capacity of processing 40,000 litres of water every hour. At a daily functional rate of 20 hours, 800,000 litres of water will be processed. This will lead to a daily production capacity of 25 kg of Deuterium. The daily income through deuterium will thus be $125,000. This means an Annual income of $45,656,250. The cost of running the Deuterium setup will be much lower as it will use the oil energy made in the settlement. The total cost including cost of oil (considering the same oil could be sold instead) for running the Deuterium plant including salaries will be $4,000,000 per annum. This leads to a net profit of $42,656,250 every year from 9131 kg of Deuterium.

Rapid advancement in Deuterium mining techniques and technology is expected in the coming decades. It is not an overestimation to say that production levels will increase by 5 times in the next 20 years while prices of Deuterium will just half. It can be said that around 2060, the Deuterium plant itself will generate $100,000,000 of profit annually.

5.1.1.2 Working of the Deuterium plant.

The Deuterium plant will obtain water from the desalination plant's freshwater production. The water will rush in every 15 minutes into this tank of capacity 15000l.
First, the Girdler-Sulfide Process will be used to increase the concentration of Deuterium to 20% in the water. The process basically relies on an Equilibrium Reaction:

$H_2O + HDS \rightleftharpoons HDO + H_2S$

Water is taken in two separate cylinders one with a temperature of 30 degree Celsius and another with 130 degree Celsius. Hydrogen Sulfide will be circulated in both these cylinders continuously and the Deuterium in the hot water cylinder will get depleted and concentrated in the cold water cylinder upto 20%. This relies on the fact that in hot water deuterium jumps from HDO molecules into HDS molecules and in cold water it jumps from HDS molecules to HDO molecules. [Girdler Sulfide Process, Wikipedia] The process has been used in the Bruce Heavy Water Plant and is also used in plants in countries like India, USA and Romania.

Next, the cold water is transferred to a Vacuum Distillation setup. The water is heated in a vacuum and repeated distillation takes place. Hydrogen Water evaporates faster than Deuterium water and this will be used to increase concentrations to up to 99%, enough for fusion reactors to use. However for this concentration, repeated vacuum distillation will be required. Also, the evaporated hydrogen water too will have a high concentration of Deuterium and this will be sent back to the Girdler-Sulfide process cylinders.

After the Vacuum Distillation, 99% Heavy water will be transferred for Electrolysis. Protium and Deuterium electrolyse at different rates and this can be used to separate Protium. 99.9% concentrated Heavy Water can be obtained in this way which is good enough for commercial purposes and Fusion Reactors. This Heavy Water will be stored in large tanks and will be sent to land on a weekly basis to the fusion companies who will buy it.

[Deuterium Separation Process source: Something Surprising Blog]

5.1.2 Oil Sale

Despite some Environmentalist concerns, oil will be mined for the sustenance of the settlement. Oil mining is one of the reasons for which government help will be needed as it is now considered an issue of international concern and any oil mining setup would need approval on many different levels.

5.1.2.1 Production Quantities

A submarine oil rig will be setup to cater to the energy needs of the settlement. It will also be used to recover energy costs during construction ($25,000,000) and also recover its own cost of construction($200,000,000). The submarine rig will not overexploit reserves and will drill at rates necessary for sustenance of the settlement with a daily marketable surplus of 100 barrels. The prices of crude oil are expected to rise

to $200 per barrel by 2040 *[International Energy Agency]*. Crude oil will be sold to local refineries and will not be processed in the refinery as management of harmful products of refining is difficult inside the sea. At an income of $20,000 per day, the submarine oil rig is expected to recover costs including maintenance by 2070. At this point, surplus oil production will be stopped.

An oil refinery will be setup for refining the raw oil into petroleum that can be used for production of energy. The oil refinery will not process the surplus as refining under the sea without polluting the water is a very difficult process and the surplus crude oil is better sold than processed and then sold.

5.1.2.2 Working of the Oil Rig and Refinery

The submarine oil rig will be a movable oil drilling system. It will operate within a 1km radius of the settlement so that repair operations are easy. Offshore drilling is usually done using semi submersible or oil platforms totally above the sea however the cost of sending drilling wells and piping under the sea and maintenance of these pipelines can be difficult. Moreover, longer pipelines lead to increased chances of leaks and oil spills. For this reason a submarine oil rig was adopted that will drill pipes and drilling machines under the sea bed and store the crude oil thus obtained. A major problem with submarine oil rigs is that underwater structures are difficult to maintain however this is irrelevant as a full fledged underwater settlement will be present nearby to house maintenance crew.

The oil from the submarine will be sent using vehicles to the refinery on the settlement. The refinery will also store the surplus crude oil that will be sold on a weekly basis to refineries on land. The refinery will remove harmful products and separate the various components of crude oil. Some components will be used for energy generation while some for materials required inside the settlement. The rest will be sold off along with the crude oil. The following image describes the working of the refinery using many fractional distillation columns and separation systems.

[Source: HowStuffWorks]

5.1.3 Underwater Research

The deep waters of the unexplored Dead Sea provide a lot of scope for research and observation. An observatory with research labs will be setup for the following functions:-

1. *Oceanography*
2. *Fresh Water Spring Research*
3. *Microbial Life Research*
4. *Research on Sea Floor Samples*
5. *Research based on Anastasi operations*
6. *General Deep Sea Research*

5.1.3.1 Oceanography

Conditions in the Dead Sea deep-waters will be recorded and analyzed in detail to pick out various factors that affect the region. Weather Phenomena will be studied and the effects of the convergence of tectonic plates near the dead sea will be identified.

5.1.3.2 Fresh Water Spring Research

Fresh-water springs have been identified in the deep parts of the Dead Sea. These springs will be studied and their inflow rates and water characteristics will be recorded. The potential of improving conditions of this fresh-water inflow will be analyzed.

5.1.3.3 Microbial Life Research

Mats of salt-water prokaryotic bacteria have been identified in the deeper parts of the Dead Sea. Normal organisms cannot survive in the salty environment because the larynx chokes when water goes inside the body due to the salt. These prokaryotic organisms are of immense interest to biologists and labs will be set up for their study. Efforts will be made to identify important genetic factors that led to the adaptation of these organisms to the salty environment.

5.1.3.4 Sea Floor Samples

Samples of the sea-floor will be taken by Researchers on EVA who will then study these in labs. The mineral content of the sea-floor in the Dead Sea is quite different from normal bodies. Sea-floor samples are important for research on the formation of the earth's water bodies. Mineral labs will study mineral extracts and samples and the resources which can be found for the habitat from deep sea expeditions.

5.1.3.5 Anastasi Operations Research

Research will also be done to improve and facilitate operations on the settlement. These include research on agriculture, deuterium mining, oil reserves etc. Special labs and machinery will be provided for dedicated research. AgroLabs focus on improving the quality and quantity of crops and the conditions to grow them and fulfil nutritional needs by new technologies and better cultivation methods optimizing the resources available. The labs will carry out plant testing and feed analysis to detect growth cycle deficiencies. They will work towards improving cropping patterns, irrigation methods, crop variety improvement, food storage and management processes.

5.1.3.6 General Deep Sea Research

Research on conditions in the deep sea and their effects on humans will be done. Anastasi will be one of the first of its kind and it's working will be a base for future underwater habitats. Records on the working of Anastasi will be maintained and will be used to provide help for other settlements.

5.1.3.7 Biotech Labs

The purpose of biotechnology labs will be to advance and create new equipment for agriculture and human aid. They will carry out the study of DNA molecules and create hybrid varieties. Biomechanical apparatus will assist in agrarian processes. Scientists and researchers will aim to develop scientific techniques and solutions based on understanding of DNA. The varieties will be improved by selection and breeding of desirable traits. Agricultural biotechnology will include genetic engineering,

recombinant DNA technology, hybridisation, tissue culture, molecular marking and other processes. Hypophysation and inducing synthetic hormones will be studied and carried out for improving fish breeding. These technologies will help increase the production in a shorter period of time.

5.1.3.8 Marine Life Research

Marine labs will carry out surveys and studies of the marine life. The aquatic flora and fauna will be vastly studied and divers will go for exploration trips. The marine organisms in the enclosed fisheries will be observed and various underwater resources will be searched and used by the settlement.

5.1.4 Salt & Mineral Sale

The Dead Sea salt composition varies from that of normal ocean water and varies with season and weather conditions. The Desalination plant which will be used to decrease the salinity of the Dead Sea will produce a lot of Dead Sea salt of commercial value for mineral companies and for production of cosmetics & other commodities.

5.1.4.1 Production Quantities

The Dead Sea water salt consists of the following minerals by mass:

67.7% Chloride and Bromide
13.5% Magnesium
10.7% Sodium
5.1% Calcium
2.2% Potassium
0.8% Others

This is very different from ocean salt that contains 85% Sodium Chloride. The overall concentration of this salt in the Dead Sea water at the depth from which the Desalination plant will take water is 277g/kg of water *[I.Gavrielli, 2003]*. The Dead Sea has a density of 1.3kg/l in the deeper parts from water will be taken. This means that each litre of water will provide for 360g of salt. The desalination pump will hourly desalinate 10,000,000 litres of water. This will produce 3600 tonnes of salt on an hourly basis. This is equal to 86,400 tonnes of salt every day and 31,557,600 tonnes of salt every year. Salt prices have been declining continuously and are expected to decline to $5 per tonne by 2040

due to the rise of desalination. This will generate an annual income of $157,788,000. The cost of running the desalination plant including the oil cost if it would have been sold instead and salaries is $40,000,000 per annum. This leads to a net profit of $117,788,000 every year.

5.1.4.2 Working of the Desalination Plant

Water from the sea will be pumped into a storage with a capacity of 5000 kilo litres. This water will go through thousands of sieve-like reverse osmosis membranes that will separate the water into freshwater and very thickly concentrated brine. This brine is then shifted to a separation tank where it is heated at temperatures around 75 degree Celsius to not only evaporate water at a faster rate but also to prevent degradation of salt. The salt that will be obtained from this process will then be transported to land continuously using a 3.2km long transport line to land and sold to large organizations, coastal areas trying to make artificial beaches, mineral companies etc.

Some of the fresh-water will be utilized for serving the needs of Anastasi while the rest will be released in the sea. The fresh-water could have been used for irrigation and other such purposes through a pipeline network however the objective is to improve the overall quality of the Dead Sea so that life can survive on it. Pumping freshwater back to the sea will reduce salinity in the area around the settlement and will allow mariculture in enclosures. 0.05 cubic km of water will be pumped into the dead sea annually. As technology advances, it is expected that by 2075, 0.25 cubic km of freshwater will be pumped annually. At this rate, by 2100 the Dead Sea salinity will be down from 34% to 10% in which fish and plants can survive thus resurrecting the Dead Sea and validating the namesake of Anastasi.

5.1.5 Tourism

Anastasi being a unique settlement will not only act as an inspiration for other uninhabited area infrastructure, but also for the common tourist. Something as huge as Anastasi being constructed under the sea will be a first for mankind. It is only natural that humans would want to visit Anastasi. Considering this, a tourism section has been set up in Anastasi.

5.1.5.1 Tourist Activities

Tourists will be transported near Anastasi in boats and even a special submarine vehicle.They will take a ride on the submarine in the dead sea which will transport them to the tourist dock in the settlement. Here they can learn more about Anastasi through the Anastasi museum and later when fish life is introduced to the area around Anastasi,

they can feel the experience of the first underwater aquarium. Tourists will be given the option to be tethered to the outer part of the settlement in the low pressure upper areas while wearing scuba diving costumes and masks. Diving activities will begin for Tourists in the mid-2040's for professional divers who want to explore the deeper parts of the Dead Sea. A less work based model of AMADA will be used for this. The following shows an example of what an Anastasi Tourist chart will look like in 2037, 2050 *(predicted)* and 2070 *(predicted)*.

5.1.5.1.1 2037 Tourist Packages

Bronze Package - 4 hrs, $200	**Silver Package - 6 hrs, $300**	**Gold Package - 8 hrs, $500**
Transport in boat	Transport in boat	Transport in Submarine
Entry to Museum	Entry to Museum	Guided Museum Tour
	Swimming while tethered to settlement	Swimming while tethered to settlement
		Tour of residential sector

5.1.5.1.2 2050 Tourist Package

Facility	**Description**	**Cost**
Anastasi Hotel	Get to stay in an Underwater hotel for upto a week!	$1000 per night
Deep Diving	Dive in a Light-AMADA suit to the deep delicacies of the Dead Sea (for professionals)	$500 for a 2 hour dive
Museum & Residential Tour	Get a chance to view the residential sector of Anastasi to get a taste of the lives of the crew and also visit the Anastasi Museum	$200 per person (3 hour long)

Transport	Visit Anastasi in a mini-submarine or a boat.	Submarine: $100 per person Boat: $10 per person
Tethered Swimming	Swim while tethered to the building in a scuba costume and get to be with fish.	$100 per person, 1 hour
Anastasi Aquarium	Experience a true underwater aquarium	$100 per person, 1 hour

Special Offer: Pay $1750 and get to do all this and get a 1 night stay.

5.1.5.1.3 2070 Tourist Package

All activities of the 2050 package in an advanced form and increased rates according to inflation plus:

Activity	**Description**	**Cost**
Underwater Adventure Park	Enjoy rides while watching fish in their natural habitat.	$500 Per Person (8 hours)
Deep Submarine Tour	Tour around the Dead Sea in a submarine and enjoy a unique sea.	$500 Per Person (6 hours)

Anastasi is expected to earn $18,262,500 annually in its initial years from tourist activities and the total maintenance cost of the same along with salaries is $3,000,000. This leads to a profit of $15,262,500. Tourist income is expected to multiply by 5 times after the construction of the hotel, aquarium and diving facilities(2050) and by 10 times after the construction of the adventure park and submarine tour (2070).

5.1.6 Agriculture and Mariculture

Agriculture and Mariculture will be practised in 5 agriculture storeys each with a plantation area of 9000m^2 and the constantly expanding enclosed area will house the fisheries and other aquaculture systems. This means a total 40000m^2 of agricultural area. A variety of crops will be grown on this area. At an expected income of $75 per m^2 every

year due to the use of efficient technology as explained in section 3.2. This leads to an annual income of $3,000,000 per year. This food will be given to the government for distribution. Fisheries will add $1,000,000 to this income making it a total of $4,000,000.

5.1.7 Space Training

Anastasi will strike contracts with government as well as private space agencies for astronaut and space settler training programmes. These programmes will let the astronauts be a part of an artificial life support environment and experience how profitable settlements function first hand. Besides this, a Neutral Buoyancy Micro-gravity Training facility will be provided using special AMADA units designed for providing the required buoyancy. The astronauts taking this training will have to work on the settlement for repair operations and also go on deep sea expeditions.
No profit will be earnt on these facilities as the ultimate aim of Anastasi is to facilitate orbital space settlements. Thus, Anastasi will become the hub of space training.

These business plans will not only be developed and maintained, they will also be monitored properly by the Administration of Anastasi. Anastasi is not only meant to improve resources and provide a simulation of a space settlement, but also to recover its vast construction and maintenance costs and turn into a profitable venture.

5.2 Cost and Recovery

Anastasi could have been a cheaper, easier to fund project. But a quality driven mindset is what has led to the need of a very big investment. It is fully understood that Fletchel Constructors wants good returns from their investment. Anastasi does not believe in reducing costs and compromising quality to increase profits *“Even if Cost is more important than quality, quality is the best way to reduce cost.” - Genichi Taguchi, Engineer and Statistician.* Instead of reducing costs, Anastasi believes in an increase cost recovery through growth approach.

5.2.1 Cost

5.2.1.1 Initial Cost

Anastasi’s first settlement is a costly settlement. These costs will have to be funded by Fletchel Constructors and will also be facilitated through Government Grants. The following table shows a detailed breakup of the initial cost of the main settlement of Anastasi (excluding future development plans).

Expense Head	**Cost in US Dollars**
Cylindrical Outer Covering	1,250,000,000
Inner Cuboidal Levels	430,000,000
Transport Lifts	10,000,000
Pipelines and Powerlines	900,000
ERL	5,000,000
Salt Belt	120,000,000
Sunlight Capture	6,000,000
Agriculture Level Interior	50,000,000
Tourism Level Interior	10,000,000
Processing Level Interior	3,500,000
Residential Level Interior	550,000,000
Waste Level Interior	7,500,000
Desalination Level Interior	510,000,000
Storage Level Interior	8,500,000
Human Exit Level Interior	2,500,000
Vehicle Level Interior (Not including inner vehicles)	4,000,000
Power Level Interior	25,000,000
Oil Refining Level Interior	15,000,000
Research Level Interior	18,000,000
Deuterium Level Interior	370,000,000
Foundation	10,000,000

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Vehicles (Including OTV & Oil)	100,000,000
Construction Contractor & Labour Costs	50,000,000
Safety Mechanism Costs (including AMADA)	2,500,000
Total	3,558,400,000

Thus, the initial cost of the settlement will be USD 3,558,400,000. This is much cheaper than the cost for constructing any human settlement in space, and a settlement of the magnitude of Anastasi is expected to cost more than 50 times its cost.

5.2.1.2 Maintenance Cost

The settlement will also have a high maintenance cost every year including salaries. The total annual maintenance cost can vary according to different factors. Maintenance costs do not include products or facilities made inside the settlement like Power, Food etc. They include raw products exported from land which are used and also technology upgrades. The following table shows an estimated annual maintenance (Level costs are excluding salaries) cost:-

Expense Head	**Cost in US Dollars**
Salaries	131,500,000
Outer bodies, both cylinder and cuboid	120,000,000
Transport Lifts	70,000
Pipelines and Powerlines	30,000
ERL	50,000
Salt Belt	2,400,000
Sunlight Capture	300,000
Agriculture Level Interior	1,400,000
Tourism Level Interior	270,000
Processing Level Interior	300,000

Residential Level Interior	60,000,000
Waste Level Interior	950,000
Desalination Level Interior	2,000,000
Storage Level Interior	100,000
Human Exit Level Interior	320,000
Vehicle Level Interior (Not including inner vehicles)	400,000
Power Level Interior	1,000,000
Oil Refining Level Interior	700,000
Research Level Interior	340,000
Deuterium Level Interior	1,500,000
Foundation	50,000
Vehicles (Including OTV)	1,000,000
Contractor Costs (Transport including on land to buyers)	5,000,000
Safety Mechanism Costs (including AMADA and diving equipment)	400,000
Consumables	100,000
Raw Materials	800,000
Total	330,980,000

The total annual maintenance cost with salaries and export costs is 330,980,000.

5.2.2 Recovery

The recovery rate as expected in the first year of Anastasi is calculated in the following table:-

Recovery Method	**Profit in US Dollars**
Deuterium	45,656,250
Oil Sale	7,305,000
Oil products sale	2,500,000
Research	12,000,000
Salt Sale	157,788,000
Tourism	15,262,000
Agricultural Products	4,000,000
Total	244,511,250

The income for the year 2038 is expected at USD 244,511,250. This number is less than the maintenance cost however this is actually an illusion. **Anastasi expects annual income growth rates of around 7%** thanks to rapidly developing technology which will increase efficiency**.** Moreover as research takes place on different business plans on the settlement, their efficiency will also increase. This growth rate will mainly come from the Desalination Plant, Tourism & Deuterium Mining setup. Research & Agriculture are also expected to show a smaller growth rate of 2%. This is because of the fact that these sectors are already quite developed and developing them further will be a slow and steady process depending a lot on developments on land technology. Oil and Refining will not see much growth as it is mainly a sustenance mechanism. On the contrary, maintenance rates are not expected to rise. At this rate, within 5 years the income will increase maintenance costs by USD 11,959,676. **Thus, at this rate, Anastasi will become profitable in 21 years, by 2059.**

Future construction projects can change this course depending on how and when they roll by. This however cannot be predicted yet.

6 Bibliography

Specific sources have been mentioned alongside the copied material. Efforts have been made to ensure that all sources are cited. Unintentional skipping of citations are regretted and we apologize to the rightful owners of the intellectual property if any such mistakes have been committed.

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