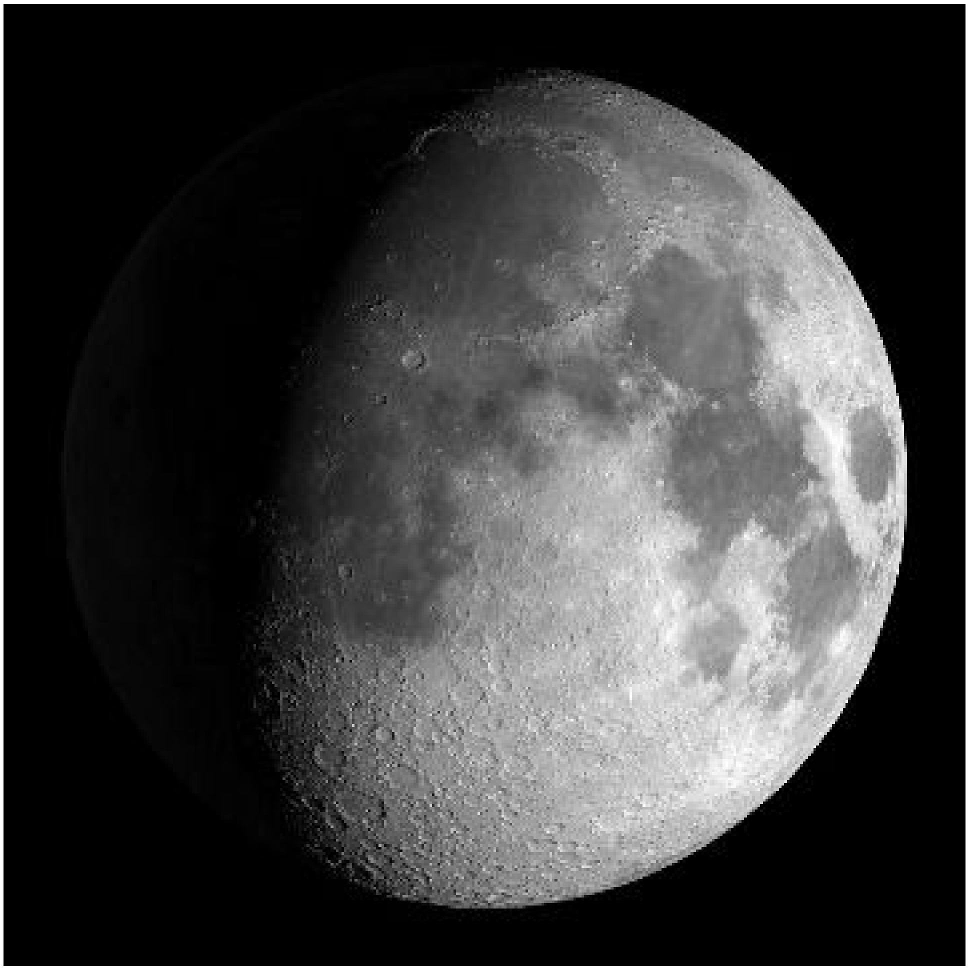
Project Report: Luna for Living (L4L)

Portsmouth College - Moon Gang



Moon Gang

09.03.2020
Year 12 BMC

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INTRODUCTION

The Task - Luna for Living

Our mission was to construct a commercial activity that could take place in 10 years relative to the year 2020. This had to be profitable as well as economical. In addition to the activity we had to provide a permanent moon base that is capable of sustaining at least 20 residents. We had to take into consideration how this could be self-sustaining and how we could make it without an extravagant use of earthly resources. Our final task was to design a transportation system to and from the moon with regular trips that can carry a load of 2,500 kg which would be composed of minimal resources and materials from Earth.

The Team

About The College

Portsmouth College remains an independent Further Education College and is a friendly, enterprising and successful College, committed to the academic and personal development of its students. We continue to grow in student numbers thanks to our innovative integration of Apple iPads in teaching and learning. Our timetable consists of a 2h45 morning lesson and a 2h afternoon lesson as well E6 extracurricular sessions that students are encouraged to take.

Abid Choudhury

I study Physics, Maths, and Architecture. I wanted to do the Blott-Mathews Challenge because I was thinking of studying engineering at University and I feel like this challenge would be a good way to begin to apply plenty of engineering techniques as well as demonstrate my own creative skills and share them with the team. I like to design and enfuse my ideas into large-scheme projects in my own time. I worked on the moon habitats section of the Luna for Living project.

Alessandro Cergnul

I worked on the Sports Centre part of the project. I'm an exchange student from Italy and I'm studying in the UK for six months. I'm currently attending Maths, Chemistry, English and Computer Science classes. I joined this challenge because I thought it would be a good way to get in touch with new people and also because I'd like to study Engineering at University. I particularly enjoyed the Blotts-Matthews Challenge as it has enhanced my knowledge about the Moon and space. I can speak Italian, English, quite a lot Spanish and a bit German.

Antons Vasiljevs

I am a first year Portsmouth College student, studying Computer Science, Physics, Pure Maths and Further Maths. I took part in the challenge as I wanted to experience what it feels like to be a part of a large-scale project, involving so many different aspects and categories. I can speak Russian, English, a little bit of Latvian and I have also studied French and German. I worked on the engineering part of the project.

Aqsa Pervaiz

I'm currently doing A Level Chemistry, Biology and Maths at Portsmouth College and I'm hoping to study Medicine at University. I chose to be a part of Blott Matthews Challenge to try something different and learn something new that was outside my interests and I've really enjoyed it. This project has improved my researching skills and it's been a great experience for me. In my spare time, I enjoy taking part in creative activities. I worked on the Life Support and Healthy Living section on this project.

Capucine Leroy-Smith

I worked on the Luxury Wellness Center and I am team captain. I am in my 1st year of A levels and I study Maths, Further Maths and Physics and intend to study particle physics and cosmology at university. I chose to take part in the Blott Matthews Challenge to meet more people and improve my research skills. In my spare time I enjoy reading books on Quantum Theory and Relativity and doing archery.

Jazmin Choudhury

I am Jazmin Choudhury, a 1st year A-level student at Portsmouth College studying Maths, Physics, and Fine Art. I hope to go on to a career in maths and physics as I find it very interesting, and I enjoy doing art in my own time. I chose to join the Blotts-Matthews Challenge as it seemed fun and it would be a good opportunity to make new friends in college. It has been a fun challenge to take part in and I have learnt a lot about the moon and rollercoasters, and generally how to do research. I have written up and researched the activity park on the moon.

Lucy Austin

I worked on the Luxury Wellness Centre part of this project. I am a first year A-level student at Portsmouth College and I am studying Physics, Maths and Further Maths; I hope to study a maths degree at university. I chose to take part in the Blott Matthews challenge to meet some different people at college and to improve my researching skills. I was also interested in experiencing what the engineering industry would be like by taking part in this project.

Max Blain

I worked on the transport part of this project. I study A Level Maths, Physics and Computer Science. I chose to be a part of this year's Blott Matthews Challenge as I wanted to experience this field of work and wanted to try something out of my comfort zone. I also chose to take part in this as astronomy and astrophysics are interests of mine and this project has helped me explore and understand more about these topics.

Hypothesis

Proposed Commercial Activity - For the activity section we came to the conclusion of having a low-gravity Sports and Activities Centre and a Luxury Wellness Centre and this will include many entertaining properties that will be very diverse compared to what's already on Earth. We consider this to be a semi-resort and will be available to all guests, offering high-tech equipment from Earth.

Moon Habitats - To reduce the load and fuel usage from the transport, we thought it would be a good idea to use the Moon's natural resources to prevent too many trips to the moon in the construction phase. An underground base in one of the Moon's lava tubes was the best option for us as it provides a wide, cool area that already has hundreds of kilometres of space cleared for a large foundation. We made use of the Moon's landscape, atmosphere, and natural resources to optimise costs and profitability.

Transport - For the passenger transportation scheme we wanted the guests to have an option of either 1 or 2 weeks with a total capacity of 18 concurrent guests as well as 12 staff. To solve this there will be multiple passenger transports with staggered schedules. For the cargo transportation we need the ability to bring resources from Earth, for repairs and maintenance, as well as spare food and water, and since most of the materials used can be found on the Moon these are not needed so often.

PROPOSED COMMERCIAL ACTIVITY

Having an activity park on the moon would attract many visitors who would be willing to pay lots of money since it is a once in a lifetime experience. It offers many low gravity activities that you just wouldn't be able to find on Earth. We are planning to sell souvenirs and gifts as these will represent the unearthly experience our guests had. All activities will be hosted on 41 km (25 mi) diameter crater Marius with a supported dome to prevent any surface damage on the surface by asteroids.

Activities that include low gravity:

- Crater slide
- Regular Gymnastics centres
- Sport car, BMX, quad bike and other offroad racing
- Trampolining with high altitude reach
- Golf courses
- Roller coasters (they have to be 6 times bigger to have the same effect, as gravity is 6 times weaker on the moon)

A theme park or activity centre would work well in conjunction with the moon habitats which we like to consider as a hotel site as people would be able to stay on the moon over the course of a week or two and visit the park each day to entertain themselves with staff supervision. The park will include gardens and greenspace to reduce the visual pollution that is already on the moon. We have also included a gymnastics centre to optimize exercise countermeasures to prevent fitness deterioration when people embark on long visits to the Moon. With low gravity and less blood volume, humans are more prone to fainting. Exercise can help increase blood volume and circulation to help prevent fainting. Staff will aid in gymnastics sessions on a regular day-to-day basis.

Sports Centre

Building a sports centre on the Moon was part of our final decision for the activity. Lots of people would certainly be excited, surprised and curious to try this opportunity. The main reason will probably be gravity, which is ⅙ of Earth’s own gravitational pull , allowing people to play the same sports as we do on our planet, but completely distorted... finding them easier, because movements are slower. Trained staff will aid in this so that they get used to the gravity.

Purposes of The Sports Centre

There will be plenty of people attracted by this new revolutionary idea and the Sports Centre is an interesting area that could evolve into a professional extreme sport zone. Moreover, for the extreme-sports fans, a lot of activities can be organised on the surface and on the craters of the Moon. The general purpose of this program will not only be fun, but health beneficial as intensive exercise can help increase blood volume and circulation on the moon.

Sports Overview

When our customers arrive on the surface, there will be plenty of things to do. Relaxing into their spacious moon habitats, having fun in the activity park and practicing a lot of sports are some the things you would expect to find here. The different arrangements of the sessions will be made so that every sport will have a dedicated day, that will allow people not to rush because they want to play all that we offer, and at the same time to understand and develop all the techniques of the activities, led by sport experts.

Structure and Facilities for Golfing

The golf sessions are the cutting edge of the sports program on the Moon, being low gravity and extending thousands of meters. As gravity is weaker, the ball will travel with a lower speed, making it easier also for people at first experience because, consequently, every movement will be slower but more precise.

GROUND FLOOR:

- Golf playground: 25 holes, multiple new generation obstacles: magnets, in addition to low gravity, as well as traditional water, sand and steep surfaces; there won't be grass on the ground, but lunar rocks and normal sand, which will add another difficulty to the sports people by being denser and rougher.

- Secondary Golf playground: Used as training before going into the proper competition game. It will be smaller and more focused on the techniques and on the difference of gravity, so it can be used by amateur players or even proper players just to get used to the gravity.

- Spa & Changing Rooms: For all staff, men, and women. The changing rooms will include showers which will neighbour a relaxation spa.

- STORAGE: For activity equipment.

ELEVATED TOP FLOOR:

- Panorama View: of both the playgrounds. If someone doesn't want to play, has already finished, or is simply waiting before starting, customers can relax and talk in this area, next to the restaurant, drink something or just watch the game.

- Restaurant/bar and Services: For snacks or beverages. The restaurant is an integral part of staying healthy and energised. It will serve a worldwide food buffet as well as important nutritional requirements.

Requirements and Power

Regarding the energy power, it won't be a necessarily large amount if golf sessions are held during the 2 weeks of light, whilst dark weeks would need a certain amount of power to lighten the whole playground, estimated to about 105000 kW power per day for the playground and facilities if we use LED stadium lights for 10 hours a day.

Track and Facilities for Circuit Racing and Rallies

Another day will be dedicated to Rallies and Circuit Racing: a mix of BMX, quad bikes, motocross, sports cars and monster trucks. The track would be composed by:

- Racing Track: Asphalt over the Moon surface and weighted vehicles for the low gravity.

- Storage and Garages: Equipment will be provided in a storage area built with the same materials used in creating all other buildings which will be lunar regolith bricks.

Requirements and Power

- If races take place during dark weeks, we would need a certain amount of power to light the whole circuit, estimated at about 75000 kWh power per day, using LED lights in order to reduce the loss of energy and increase the power produced for 10 hours a day.

Activity Park

Dome and Activity Hosting Zone

The park will be based in the Marius crater and there will also be a dome over the area with titanium alloyed metal and thick silica glass made by combining silica, sodium, and oxygen. Inspired by the domes in the Eden Project, this dome will have radiation prevention and is extremely dense due to the silica compound.

Many Structures in the park will be built on raised platforms to avoid the lunar dust, and all the pathways will also be raised, but this discloses the offroading activities and the golfing ground floor. In the park, stadium lights will be installed to illuminate the area during the 2 week period of darkness. This will be very power consuming, as a typical set of stadium lights requires around 900-1,500 kW, but since we are using a solar farm to generate our electricity, this is not a concern. The rides will also be fitted with LED lights (they are more efficient, and can be in a range of colours) to give the park a sense of atmosphere when it's dark. If the park is open for 10 hours a day, this will be roughly 15,000 kWh per day if we use the upper bound to include the LED lights - but this will only be for 2 out of every 4 weeks. In addition, the lights can be manually turned off by staff for all activities that aren't currently running. In the park there will be many rides available similar to ones in theme parks.

Roller Coaster

These would be different than on Earth due to the weaker gravity and lack of atmosphere on the moon. As this is in the airtight dome, this allows people to still get the wind-rush feeling. Since the force of gravity is 6x weaker on the moon, the cart would have much less potential energy to push it around the track. This can be solved by having more motorised chains on the ascending parts of the track to keep it going when it has to do work against the force of gravity as well as friction. But although the cart has less energy, it wouldn't need as much energy to do work done against the force of gravity as g would be much weaker, and there would be no air resistance contributing to drag. This could cancel out the lack of gravitational potential energy, reducing the need for extra motorised track. The lower gravity means the cart will accelerate much slower, so the track can be built 6x bigger to achieve the same speed as a standard sized ride on earth.

Energy

The typical roller coaster requires around 1-2kWh per ride, however this may be less due to the decreased force of gravity, depending on how fast and tall the ride is. If the ride takes 2 minutes and is on for 10 hours, it will use 600kWh per day (assuming it takes 2kWh per ride since it is a larger roller coaster).

There are other alternatives to using electricity to power roller coasters:

- The Storm Runner at Hershey Park uses a hydraulic launching system powered by nitrogen, which propels the carts at the start of the track and a magnetic braking system. The carts are then carried around the rest of the track by inertia and gravitational potential energy. These reduce the ride's power consumption by 5MW to just 2.5MW, making the ride much more efficient and sustainable.

- At Greenwood Forest Park, the roller coaster 'Green Dragon' has been designed to function completely without electricity. It consists of two carriages connected by a cable, one which the passengers board first. Their weight lifts the other carriage to the top of the track, where they can then walk to and board to enjoy the ride. However, although this ride is very sustainable, it isn't a very fast or exhilarating ride, being aimed at younger children and reaching only 25mph.

Although having a sustainable roller coaster would be much better for long term costs and the environment, they are generally more expensive to build. The Green Dragon was estimated at £500,000 to develop and build. We are also using sustainable energy from solar panels to power the resort, so consuming electricity isn't a big concern sustainability-wise.

We will be using a motorised rail to move the carts, as the energy powering the ride will be sustainable and the hydraulic launch system which we didn’t use, requires oil and nitrogen making it less eco-friendly. It will also create a much more leisurely ride for those who are less thrill-seeking, compared to the launching system which propels the carts at high speed. Having a chain to pull the carts also means this won't become a limiting factor in the height of the track - a launching system would only be able to push the cart so far up a track before it would lose kinetic energy and roll back down. The height is an important feature as we aim for it to be the tallest and biggest roller to ever exist. We plan to make it at least 200m tall, 61m higher than Earth's tallest roller. The massive height will make the ride an exciting point of interest.

Zip lines and Cable Cars

Zip lines and cable cars will be great to view the entirety of the dome and these will reach up to incredible heights. The longest zipline on Earth is the Jebel Jais Flight, going 2.8km across the Jebel Jais mountain in the United Arab Emirates. We are aiming to make one of similar length, but I could have multiple zip lines and cables. Acceleration will be much slower, so this will be a more peaceful ride unless we use 1-2kWh per ride to speed it up. The cables and wires will be attached to our 250m tall observation tower and the ride will be a much slower one on the way up.

Observation Tower

The Brighton i360 is our inspiration for the Observation Tower which will overlook all activities and sites available to guests. The British Airways i360, also known as the Brighton i360, is a 162m tall observation tower on the seafront at Brighton. The tower has a moving observation pod which slides up and down the structure. Our design will be similar to this so that the view of the dome is visible on the way up and on the way down. We are aiming to make this 250m tall compared to the 162m. The pod can take up to 200 passengers at a time. A return journey – known as a flight – takes 20 minutes. From the top visitors can get 360-degree views across the dome. The column was designed to be 4m in diameter with a height to diameter ratio of 40:1 – making it one of the slenderest tall towers in the world. The cylindrical steel sections of the tower – known as cans weigh between 45 and 85 tonnes. It took 180,000 hours of labour to make them. We will start by digging deep foundation, going more than 20m into the ground. 4,150 tonnes of concrete made using lunar regolith's basaltic properties will be used for the foundation. The 94 tonne, thick silica glass passenger pod will be 18m in diameter and can hold up to 200 people. Finally, curved glass will be used to reduce glare and improve visibility of the dome.

Other Activities

- A water park will be available which consists of an airtight space of water flow as well as low gravity water flow.
- Similar to a theme park, the activity park will include many smaller rides compared to our ginormous roller coaster.
- A cinema area will be available for the entertainment of our guests. We will also include VR experiences as well as plentiful gaming experiences.

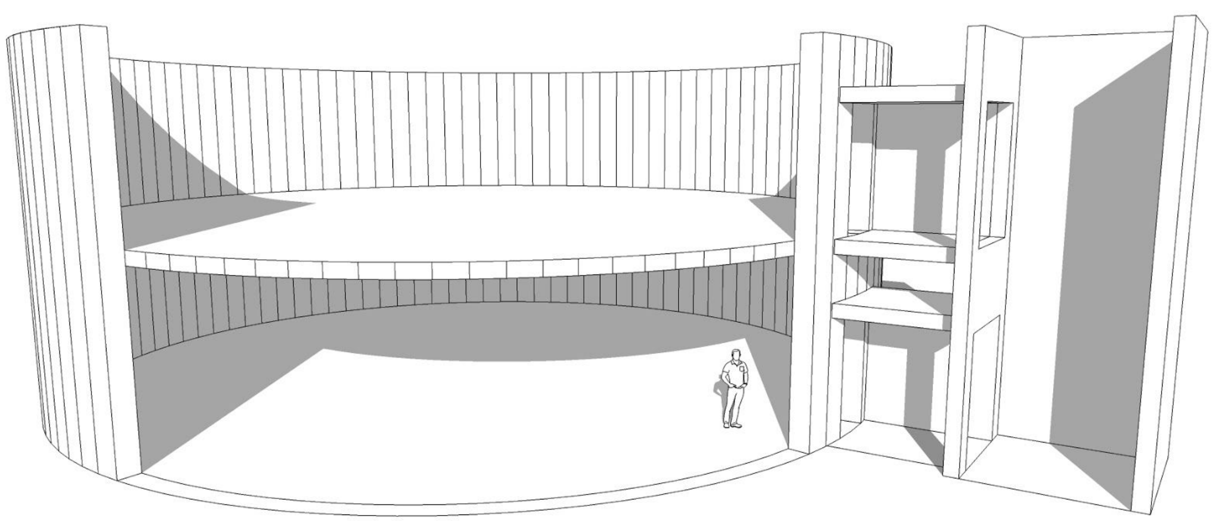
Luxury Wellness Centre

Spa & Treatment

Originally, we pitched the idea of having a resort/spa on the moon. We thought it would be a good idea to use the Moon's natural resources for treatments and we had found the elements olivine and silica (silicon dioxide) are great for this purpose. Olivine can be used in saunas and silica for treatments such as facials. The luxury part of the resort would include a spa with treatments available using lunar minerals. Moon hot rocks could be used for massages. Also use lunar silica for face masks and body/face moisturisers will be available to purchase to take home. The benefits of this material is that it helps relieve skin conditions such as eczema and psoriasis due to its anti-inflammatory properties, as well as keeping nails, hair and teeth strong due to the collagen it produces.

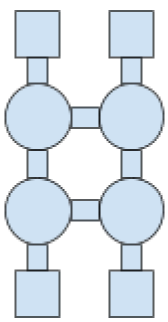
The dome is a 41 km observatory so guests can look into space and learn about planets as well as the entire universe. Hot tubs are a big part of the Wellness Centre as the hot water and jets increase blood circulation, allowing muscles to relax while reducing inflammation throughout the body. This can help improve your range of motion as well as making you stronger and more flexible. Solar power could be used to heat the water in the hot tub, so the sun's thermal energy can be used to make the water hot. Jets could pump air into the water to create the bubbles, this air can be taken from a gas tank containing the same air that we need to breath (78% nitrogen, 21% oxygen and 1% water vapour). This air can be filtered and recycled to remove CO2 and add extra oxygen to make the air breathable. A hot tub would require a significant amount of energy to run, a 240 volt heater would use about 7,500 Watts, however, it would run on solar power because there will be a solar cell farm. A 300 watt solar panel will produce 240 volts, which is what the hot tub needs. A pump attaching the hot tub to an in-built heater would pump water from the hot tub through the heater, then once heated to the correct temperature, the water is passed through a filter. The filter used would be a sand filter as it is the most efficient filter, it can filter out Biocidal chemical shock treatment will be used daily to control microbial growth, the filter will be cleaned every day after the hot tub has been used and will be replaced every 6 months, to keep the water clean. The water will be completely drained and replaced every 2 months and while the hot tub is empty, the surfaces will be scrubbed and disinfected thoroughly. Both the chlorine and pH levels will be monitored after every use by a separate pipe which takes samples when the tub is empty, and uses a pH probe to indicate if the water is at optimal levels (7.2-7.8). A chlorine measuring tool will constantly measure chlorine levels to ensure levels are between 2 and 4 ppm (parts per million).

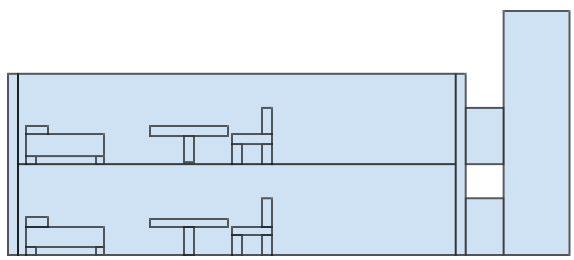
MOON HABITATS



Setup and Foundation

This cylindrical settlement is aimed to provide living space for 2 people in the first and second storey. The above image was designed on the software Sketchup. There will be a series of these cylinders with elevator shafts by their side in case guests wish to return to the surface or for evacuation. This giant structure will hold 30 people altogether. They are connected to each other for evacuation purposes and exit pathways. The diameter of each cylinder base is 20 metres and will be spacious enough for a bed, lounging/eating area, and washroom split up in sectors. Alternatively, a family of 4 can stay in 1 room with additional furniture.
The building will be located in the Moon's Marius Hills region inside a 5km wide lava tube positioned at the very bottom of a vertical lava tube also known as the Marius skylight. These tubes would be in perpetual darkness and so cold that ice could be cold-trapped in them. In addition, exploring high-latitude pits on the moon might therefore offer other opportunities to harvest water. Alternatively, the ice can provide mass cooling for the 2 weeks of extreme heat on the moon if visitors are attending at these times. This cooling system will be highly efficient because of the endless supply of ice which forms in the tubes. On the other hand, for visits in the 2 weeks of darkness and minimal warmth, concentrated solar energy can be used for heating which will be stored in large batteries. We can achieve this using giant lenses. The elevator hub on the surface is positioned on the moon's Marius Hills skylight (vertical lava tube entrance). Although the vertical tube is several hundred metres wide, the elevator shaft will be secured to solidified lunar regolith for stability and also provides great view on the way down/up. The depth is estimated to be 80 to 90 metres and the entire structure will be resting on the bottom surface. The Marius Hills take their name from the nearby 41 km (25 mi) diameter crater Marius where all activities will be hosted. This can be approached with a tunnel system from the habitats or elevator hub as the unprotected surface is too dangerous.





Materials and Structure

Walls will be half a meter thick with lead lining to prevent the various types of radiation on the moon in addition to the entire structure being underground and covered in lunar regolith (soil). Using lunar regolith as the main resource for these structures as well as for the Activity Park, Sports Centre, and Luxury Wellness Centre is efficient because it is already found on the moon and it is a powdery substance that can be used to make bricks through the process of sintering (uses focused sunlight to bond materials together) - the bricks can interlock to form a strong concrete-like structure. We can achieve making the bricks quickly with multiple sun lenses made out of glass to bind the material.

In addition to the soil, the moon's surface has a high abundance of silica which has a crystalline form and is used to create strong stone and glass compound buildings. This is the main substance used to create the crystalline dome formed with silica, oxygen, and sodium which will protect all surface activities and especially the elevator hub leading to the habitats. As well as silica, lunar regolith can be heated to form basaltic glass which will be used in conjunction with the silica as a strong compound. All this will be fitted with Titanium alloyed metal for strength and support. There are many volcanic domes setup in Maruis Hills for future hubs and stations. They average at approximately 200-500m in diameter. Titanium is another substance that is high in abundance on the moon and can be used as support for the structure of the habitats. Titanium ore can be used as an alloying agent that can be used for the accomodation, equipment for the activities, and more. Due to its low density, it is able to withstand extreme temperatures and is an incredibly strong metal, therefore making them useful for almost any environment on the moon.

Power and Efficiency

We have estimated that the total power needed to service 18 guests as well as 12 staff is 200 - 250 kW of power in 24 hours (6,000 kWh). This includes general life support, powering of equipment/appliances, water recycling, and entertainment. To counter the low-gravity on the moon, the interior walls will be fitted with cushion-like padding as well as stability beams to prevent injuries and aid with mobility around the living area. Ceiling height will be taller than the usual height in homes (about 1-2 meters taller). This housing system also applies to staff who will be close enough for aid and monitoring purposes. This design is ever expandable and can be attached to new cylinders for even more residents in the future. Lighting will work similarly to household lights and can simulate an Earth day and night cycle as all natural light is sealed since the structure is underground. Otherwise, skylights or sun tubes may be installed to provide additional natural light on the 2 weeks of light.

ELECTRICITY GENERATION

Setup

Electrical energy will be generated by photovoltaic power stations. The stations will be located on two opposite sides of the Moon and are going to be connected to the settlement via transmission lines. The stations are located this way so that there would be a constant electricity flow to the settlement, during both day and night. The issue with the transmission cables getting too hot (Moon’s surface can reach temperatures up to 127 degrees Celsius) and therefore increasing the resistance, will be solved by lining them underground, about 6m down, making sure that Sun won’t affect them. In addition, transformers will be used to increase the transmission efficiency. On each power station staff will be required as stations would be located 2730 km away from the settlement and sending repair teams every time there is damage dealt to solar farms would be non-efficient and would take too much time (2-3 days to get there).

Solar Cells

There is a variety of solar cells which could be used for this project, but we decided to use Thin-Film technology for certain reasons. Its in-field efficiency might not be the highest available on the market right now (13-18% depending on material used) compared to conventional Monocrystalline Solar cells (23-24%), however its other properties make it more suitable for our project:

- Thin-Film cells are just thin layers of PV material that can be put on different substrates, such as glass, metal or plastic, making it very easy to mass produce and setup
- Cells are flexible, therefore they can take less space in cargo ships
- Cells are usually much cheaper compared to other solar cell types

Each of these properties are crucial to success due to lack of atmosphere, meaning that smaller asteroids will not get burnt up when getting closer to the Moon, leading to constant and severe damage done to solar cells. Even if the typical lifespan for Thin-Film cell is about 20 years, this harsh environment might dramatically decrease it, prioritising lower cost and quick replacement over higher efficiency.

	Conventional PV	Thin film solar cells		
	c-Si	a-Si	CdTe	CIGS
Best research cell efficiency	25.7% [37]	14% [37]	22.1% [37]	22.6% [37]
Best module efficiency	24.4% [36]	12.3% [36]	18.6% [36]	15.7% [36]
Theoretical efficiency limit	29.43% [52]	20% [51]	32.8% [51]	33.5% [51]
Absorption coefficient	10^4 cm^{-1} [40]	(5×10^4) cm^{-1} [40]	10^5 cm^{-1} [40]	$>10^5$ cm^{-1} [40]
Current PV market share	92% [32]	<1% [32]	5% [32]	2% [32]
Annual production	~71.76 GW	~0.78 GW	~3.9 GW	~1.56 GW
Energy payback time	~2 years [42]	~1.5 years [42]	~7 months [42]	~1 year [42]
Major manufacturer	Jinko Solar [33]	Sharp [10]	First Solar [10]	Solar Frontier [10]

We will be using Copper Indium Gallium Selenide (CIGS) Thin-Film technology.

- Compared with Cadmium Telluride (CdTe) its production cost is on average 12% higher and best module efficiency reached by CdTe cell is about 18.6% compared to CIGS's 15.7%. Despite these disadvantages, theoretical efficiency that could be reached by CIGS in 10 years time is larger (about 3% more) thus being more commercially suitable in the near future. In addition, CdTe requires tellurium - material, rarity of which can be compared with rarity of platinum (on Earth), increasing the production cost in long-term period. Although tellurium can be found on the Moon, we are not planning to commit any mining operations, so CIGS is a better option for our project.
- Compared with Amorphous Silicon (a-Si), CIGS has higher a higher material demands, in addition to higher rarity of materials needed for production, whereas there is an abundance of Silicon on Earth, required for a-Si. However, the efficiency of a-Si drops by 10-30% in the first six months of constant use due to long exposure to sunlight. It is reversible, but annealing at high temperatures is needed, which would significantly increase energy demand.

Substrate used for our PV cells will be soda-lime glass as it is cheap and gives the highest efficiency when combined with CIGS, compared to other substrates.

Calculations

The total surface area required to build one power station can be obtained from this equation :

E = A*r*H*PR

Where:

E = total output energy (kWh), A = total solar panel surface area (m^2), r = solar panel efficiency (%), H = solar irradiance (kWh/m^2) and PR = perfomance ration (default value = 0.75).

The total energy required for our project (including all activities and habitats requirements) is about 98800 kWh per day, solar panel yield is 22.6% (best research result), PR is default and solar irradiance is 1.3. So the total area required is about 18799 m^2 (137x137m area). Energy lost due to transmission lines (15% energy loss) so the final result is approximately 21500 m^2. Total soda lime-glass cost (£21.5 per square meter with 2mm thickness) is about £463000. Average price to lay 0.34 meters of transmission lines is £15, so to lay 2730 km of lines would cost roughly £135000000. Adding all costs and multiplying it by 2 (2 power stations) gives the number of £383558000. The price is higher if including other minor but still significant aspects like cost of power inverters, staff salaries, etc. Transportation expenses are not included.

TRANSPORT

Vehicle Requirements

The transportation system has the following requirements.

Payload

The system payload consists of:

- People, 9 passengers per flight
- Food, water, and all other sustenance for guests and staff
- Materials for Buildings, Maintenance etc.

Systems and Support

In addition to the payload the transportation system will utilise vehicles with additional systems and support for:

- Payload support e.g. life support systems, refrigeration, storage, passenger accommodation
- Safety, escape and rescue
- Navigation and Communication Systems
- Flight Control
- Engines
- Landing and Take-off Gear
- Crew Systems + accommodation, Crew of 3 people (Chef, Flight attendants, flight engineer)

Safety, Availability and Reliability

In designing a transportation system, the aspects of safety and availability will have huge implications on an acceptable design.

Journey Requirements

The transportation system shall support operation of the following schedule:

- Earth to the Moon, 3 days. High gravity take-off and landing.
- Refuel and refurbish turnaround in 14 days.
- Moon to Earth, 3 days. Low gravity take-off and landing.
- Refuel and Refurbish, 8 days.
- 20 Days total.

We also need to consider the schedule of:

- Flights.

- How frequent.
- Passenger capacity.
- Safety and backup rockets for moon evacuation, or rescue.

Requirement Analysis

Requirements indicate two types of high priority requirements

Payload of Passenger ship:

- Payload of Passengers 9 times (100kg each).
- Staff 3 times (100kg each).
- Space suits, life support (100kg).
- Sustenance for the journey over 6 days (60kg).
- Buildings and passenger quarters (600kg).
- 10,320kg total cargo.
- Passengers to be carried in utmost safety.

Payload of Cargo ship:

- Cargo of supplies (food and water) for guests and staff 30 people for 14 days at 20kg per day (8,400kg).
- Other provisions (10,000kg).
- Maintenance and resupply (30,000kg).
- 38,700kg total cargo.
- Loss of cargo is acceptable as long as there are no knock-on effects, for example, pollution or shortage of supplies.

The journey from Earth to moon:

- Requires a high thrust and energy capability to escape Earth's gravity.
- Low gravity, zero atmosphere landing capability

The journey from Moon to Earth:

- Low gravity take-off requires low thrust and energy
- Re-entry to Earth's atmosphere
- Landing in Earth's gravity

Transport Design

Because of the differences in requirements for exiting Earth's gravity and re-entering Earth's atmosphere it has been decided to split the journey into a number of stages optimising vehicle design for each stage.
Using a space station positioned in a low to medium Earth orbit will increase efficiency and lowers the risk of the Earth to Moon stage, whilst also giving the rockets enough time to be sent back to Earth to be refurbished for their

next use. The space station will have 2 lunar transport units and 2 passenger docking ports.
During the flight, passengers will entertain themselves with cinema, food and VR experiences. They will also have time to practice getting used to the weightlessness. Before landing, passengers are required to rest for a long period of time to better their physical health. Sleep is involved in healing and repairing your heart and blood vessels.

Journey for passengers

Each passenger rocket will take 9 guests. The rockets will be alternating 1 week apart from one another.

- Earth to Moon
  - Rocket takes passengers from Earth Spaceport to a space station in Earth's orbit over the course of 1 day.
  - Passenger compartment remains at the space station and is reused as part of the re-entry vehicle. Meanwhile the rocket returns to Earth for refurbishment.
  - Passengers transfer from the space station into the Lunar transit vehicle.
  - Lunar transit vehicle travel 2 days to reach the Moon.
  - Lunar transit vehicle maintains lunar orbit during guest's stay.
  - Passenger lunar lander sent to the moon from the transit vehicle.
- Moon to Earth
  - Passenger lander sent back to the transit vehicle.
  - Lunar transit vehicle exits lunar orbit and returns to Earth space station over 2 days.
  - Passengers transfer to Earth re-entry vehicle.
  - Earth re-entry vehicle lands at Spaceport on Earth over 1 day.

Journey for Cargo

Cargo rockets will be sent once every 2 weeks.

- Earth to Moon
  - Rocket takes cargo into cargo transfer orbit.
  - Cargo module is attached to the Lunar transit vehicle and the rocket returns to Earth for refurbishment.
  - Lunar transit vehicle travels 2 days to reach the Moon.
  - Lunar transit vehicle maintains lunar orbit during guest's stay.
  - Cargo Lunar lander sent to the moon from the transit vehicle.
- Moon to Earth
  - Cargo lander is loaded with materials to be sent back to Earth e.g. waste, lunar products.
  - Cargo lander sent back to the transit vehicle.
  - Lunar transit vehicle with passengers and cargo exits lunar orbit and returns to Earth space station over 2 days.
  - Cargo module reconfigures for Earth re-entry.
  - Cargo module lands on Earth for retrieval over 1 day.

Candidate Solutions

Passenger Rocket = SpaceX Falcon 9

- Total carrying capacity of 22,800kg.
- 75 of 77 success rate.

Cargo Rocket = SpaceX Falcon Heavy

- Total carrying capacity of 63,800kg.
- 3 of 3 success rate.

Lunar Transit Vehicle = NASA Orion

- Return payload may be a concern.
- In production.

Critical Considerations:

- Risk of failure.
- Safety standards.
- Untested vehicles.
- Current availability.
- Environmental damages.
- Cost effectiveness.

SUSTAINABILITY & HEALTHY LIVING

Life Support and Respiration

Concern: The main concern of being on the moon is breathing without constantly wearing a spacesuit, which can be both uncomfortable and heavy; this will defeat the purpose of having a resort on the moon.

Solution: The best way to solve this problem is being inside airtight living structures. This structure will have an artificial atmosphere similar to the one on earth, so the guests can move around like they would normally. The hotel will have an airtight mechanism and outside the hotel, we will build an airtight living structure inside a crater, this is where all the outdoor activities can take place without the guests constantly being in spacesuits.

Why Building an Airtight Structure is The Best Idea:

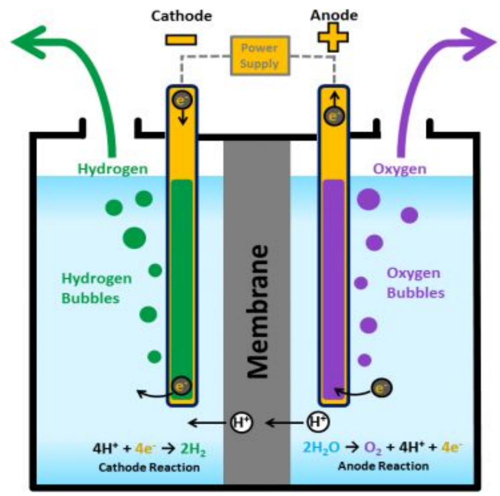
- Makes it easier to control the levels of oxygen, carbon dioxide, nitrogen and other gases
- Maintains the right pressure

- Controls trace contamination
- Filters out harmful microbes that can enter from the atmosphere
- Atmosphere is similar to one on Earth

Producing Oxygen

Oxygen will be produced by an electrolyzer that uses electricity from solar panels to break up water molecules into oxygen and hydrogen. The oxygen produced will be released into the airtight structures to create an artificial atmosphere, to provide oxygen for breathing and respiration. The hydrogen produced will be used in the Sabatier reaction to produce the water again.

This is an efficient method because the water being used can be restored by using the hydrogen from this reaction to produce water in the Sabatier reaction, which can be used again to produce the hydrogen and so forth. This cycle method prevents any unnecessary waste being produced and is an efficient way of recycling. Another reason this is a good way to produce oxygen is that it is a chemical-mechanical system, which is much more compact, less labor intensive, and more reliable than a plant-based system, however, the problem is that it will be more expensive as a long term solution and this will require a lot of energy and large volumes of water to meet the demands. We will also, in the event of breakdowns, need to maintain redundant supplies of oxygen for the safety of the people there.



Energy Requirements

The energy requirements depend on the electrolyzers used. The most commonly used are alkaline electrolyzers and proton exchange membrane (PEM) electrolyzers.

Alkaline electrolyzers have a lower efficiency of 70% but they are cheaper because they use less expensive catalysts like nickel. Whereas, PEM electrolyzers have a higher efficiency of 80%, however, they are more expensive due to their use of expensive catalysts like platinum. Using PEM electrolyzers can be cheap if they produce enough hydrogen to lower the cost. By either method, producing 1 L of hydrogen requires 50-55 KWh, so the energy required to produce 1 L of oxygen will vary around this.

I've come to the conclusion that using PEM electrolyzers will be better than using alkaline electrolyzers. This is because of their higher efficiency which is said to increase even more in 2030 to 86% and they're likely to be cheaper if a large quantity of hydrogen is produced. On the moon, we will need large amounts of both hydrogen and oxygen so this method will be useful and cheaper than using alkaline electrolyzers.

Calculations

An average adult takes in 7-8 litres of air per min from the atmosphere, so the maximum amount of air breathed in 1 hour is:
8 x 60 = 480 litres per hour.

In 24 hours, an average person will breathe in:
480 x 24 = 11520 litres of oxygen
The air only consists of 20% oxygen which of only 15% is exhaled so 5% is actually consumed. Therefore…
11529 x 0.05 = *576 litres of oxygen is consumed per person per day.*
Any sports and exercise will require more oxygen and we have made sure of having extra supplies of oxygen

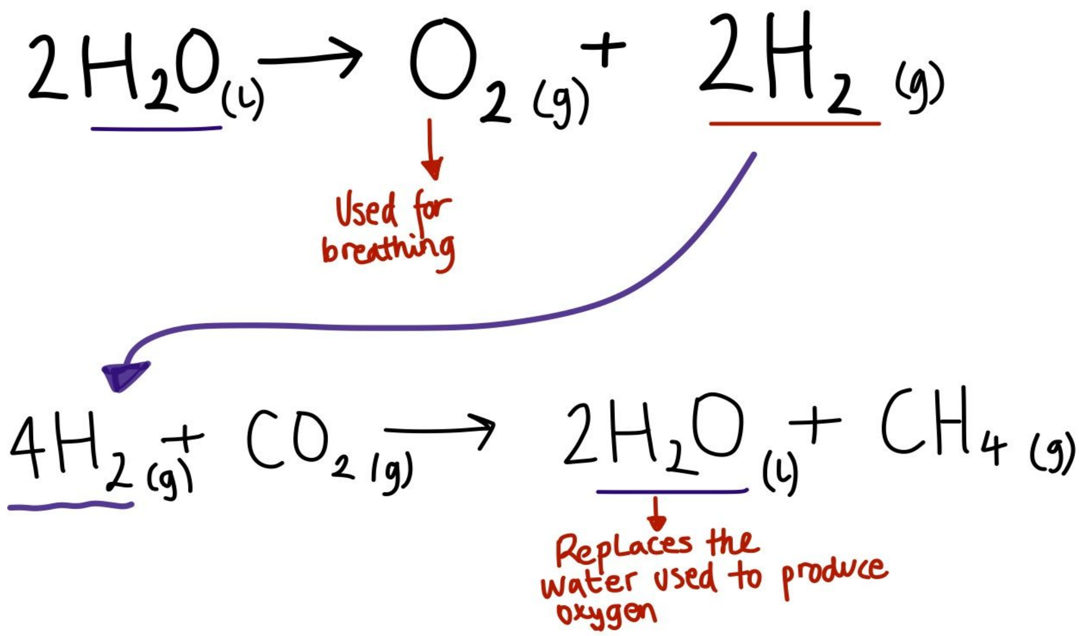
During certain activities that are outside the living structures or travelling, guests will be required to wear spacesuits and oxygen cylinders. We have decided to use the “Mini M-6” oxygen cylinder with the flow rate of 0.5 LPM, which can last up to 16.5 hours. It can also last during any events of breakdowns, ensuring the safety of the guests. Another benefit of having a Mini M-6 cylinder is that it has a diameter of 3.2 inches and a height of 11.2 inches, so therefore it’s small and will be easy to carry around.

Removal of Carbon Dioxide

To maintain the level of carbon dioxide, it will need to be removed so the level of carbon dioxide does not accumulate. So therefore, carbon dioxide is removed from the air to be used in the Sabatier reaction. Carbon dioxide will also be recycled from the exhaled air to be used. This is a clean and efficient process making sure that there is no harmful waste that the guests might be exposed to.

Producing Water

Water could be produced by the Sabatier reaction, by using a machine that will be used to combine the hydrogen, from the electrolysis of water, with excess carbon dioxide from the air in a chemical reaction, so that removes carbon dioxide from the air, to produce water and methane. This method is being used by NASA and the ISS. The water produced would partially replace the water used to make oxygen, so less water would be needed to produce oxygen over time. This makes it easier as it will decrease the amount of water transported to the moon. The methane produced in this reaction would be vented to space, so the level of this greenhouse gas does not increase in our artificial atmosphere or it will be broken down into carbon and hydrogen, which can be recycled back into the reaction.



However, you'd require twice the hydrogen to produce the same amount of water. But this can be solved by recovering the hydrogen from the methane by the method of Pyrolysis. Pyrolysis uses a lot of heat energy to separate carbon, which can be stored in its gas form, and hydrogen, which is recycled back into the reaction. This is highly efficient with a conversion rate up to 95%.

The water produced in Sabatier reaction will be used for the production of oxygen and other everyday purposes like washing, cooking and cleaning. Water is also needed to clean after certain sports activities and it's needed for the luxury wellness centre.

Water has to be transported in the form of ice to the moon, in boxes that are temperature and pressure controlled. This water will be mainly used for drinking as it will be pure. Based on the calculations, 50L of water will be needed per day for drinking purposes.

We could also mine water from the lunar soil. The water would need to be mined and then refined, so it's safe enough to drink. It would take approximately one ton of lunar dirt to extract a litre of water. This would make a scarce commodity, but if used responsibly, it could be used to grow plants, drinking and with the other ways, it could be enough to maintain a colony on the moon. This would also eliminate the need to transport blocks of ice from Earth by reducing the difficulty and cost. However, I came to the conclusion that this would require a lot of energy and it would not be worth the yield, so we have decided not to use this method. It will be an inefficient method that will waste energy and materials.

Calculations

To prevent dehydration, an average adult should drink 2 litres of water. It changes with gender and weight. It varies around an average adult male drinking 3.7 litres and an average adult female drinking 2.7 litres.

If one person drinks approximately 2 litres in 24 hours, then around 25 people would require a maximum of 50 litres of drinking water per day.

Food and Farming

Plants in Microgravity

Concern: In an orbiting greenhouse, freely-falling plants lack the downward pull of gravity, and so water spreads out too evenly in the soil-like material around their roots, making it more difficult for air and water to reach the roots, preventing the growth of plants.

Solution: The best way to solve this is by using soil with granules of a certain size. If soil grains are too big, the roots won't get enough water; if they're too small, they will not get enough air. Plants need oxygen and carbon dioxide, and the roots need water and oxygen at the same time. So plants will need to grow in a porous clay-based growth media and fertilizer. The clay media surface roughness, surface area and particle size traps air and absorbs water such that the root has both at the same time. It also helps distribute water, nutrients and air in a healthy balance around the roots. In addition, there may be insufficient air circulation in an orbiting habitat so that plants can suffocate on their own "exhaled" oxygen with the use of fans to keep the air moving. Otherwise, the roots would either drown in water or be engulfed by air. As there's no gravity, plants use other environmental factors, such as light to grow. LEDs are placed above the plants to produce a spectrum of light suited for the plants' growth.

As well as feeding the guests the crops we grow, we will also provide them with high quality food. We will transport quantities of pre- packaged meals that will need to be cooked at the resort. These pre-packaged meals include meat, vegetables and dairy to make sure our guests are eating like they would on Earth. The food calculations provide the quantity of food that will be needed to be transported to feed our guests.

Food Calculations

For an average adult male, the daily calorie requirement varies around 3000 calories when active.
For an average adult female, the daily calorie requirement varies around 2300 to 2500 calories.
An average person eats up to 2.5 kg of cooked food per day. So 50 kg of food would be required to feed 20 people per day. 50-60 kg of food per day would be needed for 20-23 people.

Making a Profit From Our Moon Food

Our team had an idea to make profit from the crops we grow on the moon. The idea is to transport a certain quantity of them to Earth to sell them as “souvenirs” to the guests, as well as people in general who are interested in trying “Space Food”. This could be an exciting way for people to be interested in joining our Moon Resort experience and it will introduce something new and different to the market.

Energy Requirements

The only electricity needed for growing crops is from using fans to circulate the air around the plant and LED lights that provide energy for photosynthesis in the plants. Fan ventilation can use from 0.5-1 KWh of electricity, depending on the size and efficiency of the fan. Using regular cheap fans will be efficient as replacing them wouldn't be expensive and the efficiency of the fans will be constant, making sure the environment the plants grow in does not change.

For the lights, we will use G8LED grow lights. They are very efficient at growing healthy plants by using a lower usage power. They reduce the total amount of electricity needed and minimize the heat output, this prevents any energy being wasted as heat and lowers the cost. The light has a power draw of 0.38 kWh and they are very cheap with the cost of around £0.10 per hour. The lights and fans will constantly need to be on as we will be continuously growing crops and producing fresh food to be eaten.

Cooking at the resort will use a lot of power and energy, especially if we are cooking multiple times a day everyday. Cooking necessities like ovens and microwaves use around 1-5kW, ovens tend to use around 2.4 kWh. Depending on how many hours we cook per day, the energy requirement will be different for each day. However, if we cook for around 10 hrs a day, then the maximum amount of energy needed for a day is around 50 kWh.

In total, the maximum amount of energy required for the G8LED lights for one day is 9.12 kWh and for the energy required for one year is around 3329 kWh. For the fan ventilation, the maximum amount of energy required for one day is 24kWh and for one year, 8760 kWh is required.

Pre and Post Moon Health

After long stays (ranging from a few months to a year) in microgravity environments, astronauts have to readjust to the much stronger pressure of Earth. They are required to perform medical tests each day during the first few weeks of their return to ensure they are in good health, and also to benefit research.
Although customers wouldn't be away from Earth for more than 3 weeks, medical tests should still be carried out on them once they return as they will still need to readjust to the different environment.

Customers should also be tested before they go to the moon, to make sure that the environment there isn't putting them at too much risk. For example, pregnant women and those with serious asthma should not be allowed to go due to the lower gravity and lunar dust which could cause many complications for them.

There should not be an age limit, as older people may still be healthy enough to go, but there must be a minimum age as children who are still developing may be affected by the different conditions. We have agreed on the minimum age being 16, as people have nearly stopped growing by this age so their development will not be affected by the environment.

Lunar soil

Lunar dust may cause a number of different problems for the space resort, especially in the theme park where they will be walking around without the protection of space suits. If the dust is inhaled, it can increase the risk of health complications and damage the lungs and respiratory system. The dust is also very abrasive since there is no atmosphere or wind to erode the particles into rounder shapes like on earth. This means the dust will wear away people's shoes very quickly and could damage structures that we build on the lunar soil.

To solve these problems we can provide people with strong shoes when they are walking on lunar soil without suits. We can also put rules in place that require everyone to wear long trousers and long sleeves.

To prevent them inhaling the dust in the air (since there will be wind and air inside the dome), we can issue masks to filter the air that they are breathing and try to reduce the dust in the areas that they are in.

Lunar soil on the moon ranges from 5-10m thick, so we will not be able to simply sweep it away. To combat this problem, we can build platforms to walk on that are raised slightly above the dust that will make it safer to walk on and keep people away from the dust so it does not get kicked up into the air.

OVERALL CALCULATIONS

Sports Centre (during 2 week darkness) = 180,000 kWh per day

Sports Centre (during 2 week light) = 17,500 kWh per day

Sports Centre Average = 98,750 kWh per day on average

Activity park (during 2 week darkness) = 16,470 kWh per day

Activity park (during 2 week light) = 1470 kWh per day

Activity Park Average = 8,970 kWh per day on average

Moon Habitats (during 2 weeks darkness) = 9,000 kWh per day

Moon Habitats (during 2 weeks light) = 6,000 kWh per day

Moon Habitats Average = 7,500 kWh

Stadium Lights = 15,000 kWh per day

G8LED lights =9.12 kWh per day

Total Energy Consumption Per Day on Average = 130,229.12 kWh

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