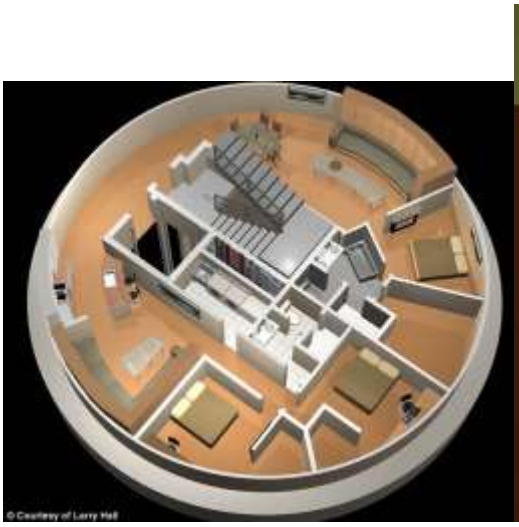
CITADEL

Welcome to the lunar city of Citadel, founded 110 years ago in the year 2030. Citadel, which means Fortress in French, is located on the south pole, on the edge of the crater de Gerlache. Some of our location's geographic features are impact craters, highlands, and rilles, which are the remains of collapsed lava tubes. The highlands were formed by the eruption of hot molten magma during its creation, flowing out onto the surface, and the craters are formed from smaller objects hitting the Moon.

In Citadel, our residents live a safe, healthy, and comfortable life. Citadel has a population of 10,146 human residents, with an advanced education system for people of all ages, including colleges and community colleges. Recreation sports include micro-gravity soccer. Essential aspects for our citizens are their health, food, electricity, and water needs. Engineers, miners, doctors, and police officers are some of our important jobs. Citadel's industries are lunar construction, indoor agriculture, ice mining, food industry, and the solar energy industry. These are all essential things that contribute to our city.

In Citadel, our homes are located inside protective domes, which are

the most potent structure. They are partially subterranean. There are many floors for each of the domes. Each floor houses one family. These structures contain about 8-9 levels, with families of around 4-6 on each floor, forming a multilayered housing complex. They are built with the moon's resources, including lunar regolith, oxygen, iron, titanium, silicon, magnesium, and aluminum. Under each home are emergency basements, which contain supplies and separate oxygen production systems. The underground rooms also hold emergency water and food supplies if needed to go into a lockdown. Walking between domes through connecting tubes can be both educational and enjoyable. Several tubes have live streams of current events in space and gallery walls of paintings.



Transportation on the outside of the domes is by Cable lift, similar to ski lifts, with pressurized vehicles running along overhead cables, driven by wheels that run on the wires. This right choice of transportation is relatively inexpensive and easily accommodates temperature changes from the crater rim to the crater's bottom.

Citadel has many different services that assist our residents. We want to highlight the educational system, health care centers, and trash services.

The education system consists of traditional instruction but includes hands-on service-learning projects. Students will spend part of their time contributing to the needs of their lunar environment while learning vital skills to help their community grow as they do. This system is uniquely tailored to meet the interests and abilities of the students.

Citadel’s health care is a publicly owned system where the residents can go to an emergency center to get treated. The health care system rescues residents with emergency vehicles. The hospital was created by and locally operated by citizens.

The trash services in our city are technologically advanced. After robots pick up waste from residents' houses, it goes to a recycling plant, where it is made into materials used to 3D print our tools and supplies used in our city. The trash services in our city are technologically advanced.

Citadel´s maglev provides a unique form of travel. It consists of two strong magnets repelling against each other to cause less friction and travel faster. The magnets allow the train to go up an incline much faster than everyday transportation and reduce sounds and vibrations that disturb the dome-like schools trying to learn or news for Citadel's residents. If there is an electrical problem with the lights or plumbing inside the carts, you can

stand up under the maglev to make fixes easier and more efficient.

To control meteor damage, Citadel uses space probes to send heavy objects at the meteor and deflect it. If evacuation is needed, Citadel's bunker is airtight and big enough to fit all citizens. A bunker is built into each of the apartment complexes so that the citizens can evacuate quickly. In case of a significant crisis, escape pods are used to evacuate the city. They eject far away from the dome and have plenty of supplies to last for around a week.

Two of the primary resources Citadel uses are regolith and water. Regolith is the primary material used to build structures and tools, consisting of iron, silicon, manganese, magnesium, calcium, aluminum, and titanium. First, the soil will be extracted by rovers, managed by electrical and mechanical engineers, then molded into bricks. These bricks will be used like ordinary bricks on an Earth house, except there will not be any mortar put on the bricks; they will automatically mold into each other to create an airtight seal. All leftover regolith that is not turned into bricks is used for machines like rockets, robots, and rovers. Regolith is, in its dust or gaseous form, toxic to the touch, smell, or sight without protection. Polymer engineers had to add a polymer skin to our spacesuits to protect our citizens from these hazards.

Now, the water can be found in many craters near ours. When we need to mine ice, our rovers, called drovers, designed by mechanical, and a water resource engineer, use drills custom-built to tunnel into the ice. Then, they transport the ice back to the city to be heated, filtered, and converted into usable water for our plumbing purposes and for our

residents to drink. Something we must watch out for is water contamination from the drovers or our drovers breaking down, causing us to lose precious water. If this event is to happen, we could refilter our urine. However, it is better for us to extract it from the Moon than to transport it all the way back from the Earth.

Our city lies under a massive dome. This dome will protect us from different natural and unnatural hazards. Domes are one of the most vital geometric objects used to construct buildings, and that is why we are using it. To make sure that our dome is safe and sound, we need to have a plan. Once we figure out what we are going to do, we build a prototype. We then test our prototype in many ways to make sure that it could hold up in other circumstances. If our prototype isn't working the way we want it to, we try again. After our prototype seems to hold up to our standards, we build our dome. We must take our time to do this because one small wrong move can change the whole thing and mess it up. Once our dome is built, we start building the houses above the ground and move people into them.

Some compromises we must make are limiting the amount of water we use daily and reuse as much water as possible. With 1.3 trillion tons of ice, our residents will last a long time if we compromise like this. Another thing is the consequences. One of those consequences is toxicities. We have very little knowledge about regolith, meaning that it could be toxic to the touch, smell, or sight without protection. Or maybe regolith isn't as substantial as we think.

The types of Engineering mainly focused on are Civil Engineering, Environmental Engineering, and Aerospace Engineering. Civil Engineering

is needed to build and keep expanding our city. It also revolves around building roads, bridges, dams, and similar structures. This type of engineering would help us make our way around the Moon. We also chose environmental engineering because we want the living environment to be as perfect as possible, and we don't want anything to fail, especially on the Moon. If something were to fail, we should fix it and not depend on the earth's resources. Aerospace engineering revolves around building planes, missiles, and spacecraft. We would use aerospace engineering to build even more spacecraft and vehicles to use on the Moon. We also incorporate other types of engineering, like mechanical engineering, to construct our rovers.

Living on the Moon can be challenging because of all the hazards, including meteors, moon dust, and radiation. We have come up with a great idea that will keep our residents safe and healthy. It is to make a large dome around our city to contain atmosphere. It will be made of high strength glass, which is silicone. To protect the residents from solar flares, we can put as much lead in things because it is a barrier between you and the harmful rays.

On the Moon, solar power is beneficial, but the tradeoffs of using solar energy on the Moon won't get constant sunlight. We are located on the south pole of the Moon, so we will not get a lot of it, but we will have almost constant sunlight. If we ever happen to run out of Solar Energy, we will pertain to Mechanical Energy. As our water is being filtered, we turn it through a large turbine, creating Mechanical Energy.

Word count- 1490

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Laughter City

Word Count: 1496

In 2035, governments worldwide united and began a new age in humanity, the Space Era. This change was ushered by the advent of fusion power, skyhooks, and powerful, more efficient rockets. The moon was an ideal first step because of its proximity to Earth, large deposits of rare elements, and billions of years of He_3 (a helium isotope ideal for fusion) buildup in the regolith (moon dust). Hehehe Incorporated was founded in 2036 to mine these resources, and continues its operations today. To sustain itself and its facilities, Hehehe established a base of scientists, engineers, and roboticists. By 2085, it had grown to 90,000 people and was named Laughter City. Urban planners and civil engineers developed an efficient city infrastructure that became the model for cities around the solar system.

Laughter City (LC), the largest on the moon, is located in Kepler Crater (30 km diameter) at 8.1° N 38.0° W. Kepler was chosen because of its location in the highlands, an area with large amounts of regolith. It's powered by a Dyson swarm — a myriad of mirrors surrounding the sun that reflects a large portion of the sunlight to collecting stations, which then converts the energy to electricity. As of 2147, Laughter City has a population of 935,047 comprised of many different ethnic groups and a median age of 33.

The city is composed of two sectors, one for civilians and a smaller one for agriculture. Both lie completely underground for protection from meteorites and harmful radiation. Incoming spaceships carrying supplies and passengers reach the city's underground spaceport through reinforced airlocks. Lining the sides of the first sector are honeycomb-shaped buildings used for housing and small businesses. The center part (called

the city center) imitates Earth with parks, earth-like buildings, climate control, artificial gravity, and simulated sunlight. The multilayered agricultural sector houses vats for growing genetically modified yeasts that taste, look, and have the same nutritional value as real foods, as well as aeroponic systems for growing traditional fruits and vegetables.

Figure 1: Laughter City

Due to a lesser amount of resources available, early settlers realized the need to multipurpose many things. Engineers and roboticists from Hehehe Inc. designed the Nano-MicroBot (NMBee), a small bee-shaped bot that, with a swarm of others, could form into an object. Though it remains the most innovative feature of Laughter City, frequently used items are now manufactured out of more permanent materials.

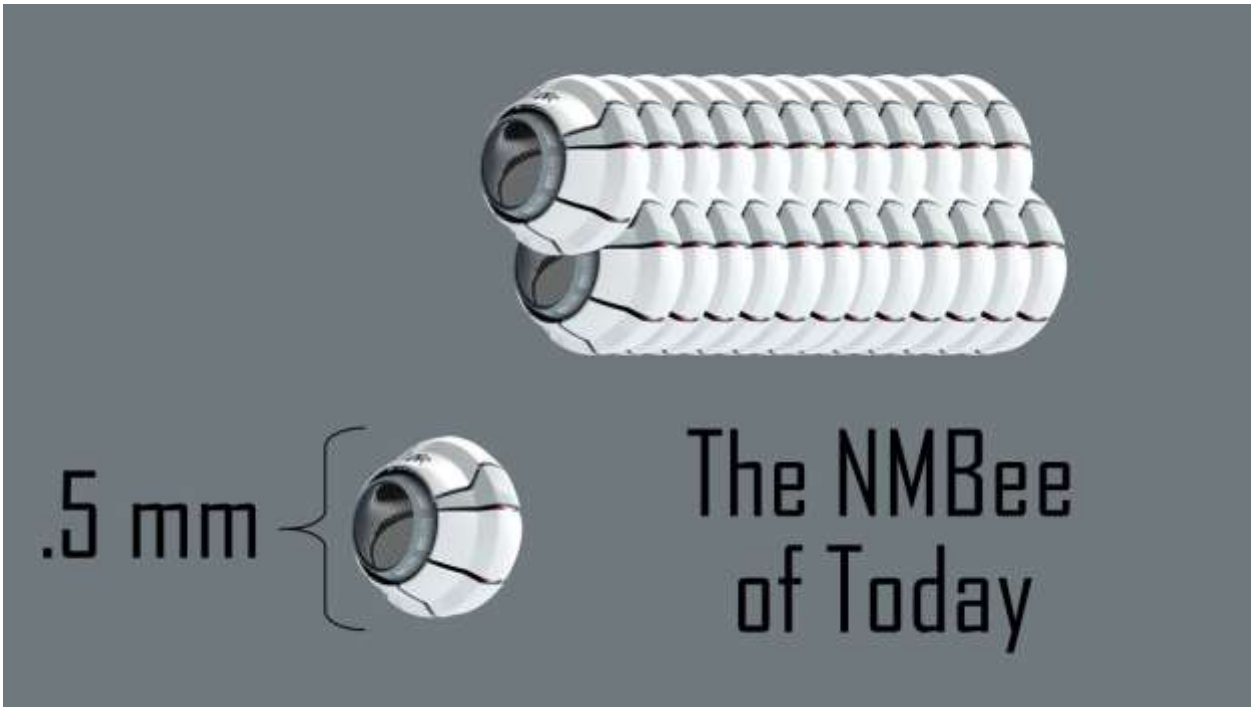

Figure 2: The NMBee

A Day in the Life of an LC Citizen

It's another beautiful morning here in Laughter City. Actually, most days are beautiful, thanks to ARC (artificially regulated climate). ARC varies the climate, providing seasons, and we even enjoy occasional rain or snow.

I reach over and put my NMBeeController behind my ear. It reads my brainwaves and transmits them to my NMBees. It also monitors my physical and mental health. After a quick breakfast, I head to the city center in my pod.

Pods are the means of transit for all citizens in LC. They travel between honeycombs via electromagnets, charging up at the same time for flight in and above the city center via advanced miniature magnetoplasmadynamic thrusters. After arriving at Hehehe Inc. headquarters, I head to the robotics department where I work as a junior roboticist

developing new robots and software, and lead the recycling of old ones. For my lunch break, I go to one of the ten parks in the city center, where I see rabbits, squirrels, and birds.

At 16:00 SST (the System-wide Standard Time is used in all lunar cities due to 700 hour days, and is the standard for all settlements in the system), I head back home. Tonight, I enjoy a dinner of yeast steaks and potatoes, as well as real fruit for a fruit salad. Nutrients from leftover foods are extracted and used as fertilizer.

City Services

If a fire breaks out in the honeycombs, the immediate area is isolated from the rest of the city using airlock systems. The air is then pumped out after the citizens inside the area put on their spacesuits. Regolith, when ground into a powder and mixed with other materials, is effective at extinguishing fires. This is utilized in the city center by the fire department.

Due to Universal Basic Services (UBS) and early prevention, crime is virtually nonexistent in LC. UBS provides essential services (housing, education, food, transportation, and a basic income) to everyone. Hard work is always rewarded, and previous benefits are not deducted. The NMBeeControllers monitor citizens' emotional well-being, and help is provided to those who need it, preventing crime in the first place.

NMBeeControllers also help doctors by tracking the physical condition of the citizens. Pods allow for medical assistance to easily and quickly reach anyone who needs it.

Schools in LC are blended, ability-based, and year-round (six weeks on, two weeks off). This system allows for better learning and less burnout for staff and students.

Laughter City's Usage of Lunar Resources

There are three lunar resources essential to Laughter City's ongoing prosperity. The first, silicone, is mined by robots from moon rocks in the form of silicate. It's used in protection from moonquakes and the manufacture of robots and other technologies. Even before the moon was settled, it was known that moonquakes would pose a significant danger to people and infrastructure on the moon. Using mostly silicone, along with other resources available on the moon, scientists, chemical engineers, and material engineers developed Oosilane. Oosilane is a non-Newtonian fluid — meaning it changes its viscosity when subjected to different pressures. One example of a non-Newtonian fluid is Oobleck, which is capable of stopping a bullet. Working in tandem with civil and structural engineers, a space was then carved out around the city sectors and spaceport, which were anchored to the surrounding moon rock by tungsten-steel poles. The space was divided up into sections using a membrane made of durable polymers. Each space was then filled with Oosilane. When a shockwave hits the membrane or one of the supports, the Oosilane hardens. The act of hardening absorbs a large portion of the most powerful moonquakes. A second layer absorbs the remainder. The two layers together absorbed 99% of the strongest moonquake in the history of LC. The hardened Oosilane has the properties of silicone and Sorbothane (the most shock-absorbing solid known). If a secondary wave hits the Oosilane before it has time to liquify, the two layers of hardened Oosilane are capable of stopping most of the shock. However, these shockwaves are more dangerous, and can cause damage to the city's infrastructure. During strong moonquakes with possible secondary shockwaves, citizens are instructed to stay in the honeycombs. Structural and civil engineers designed them to distribute the tremors and dilute the effects. Citizens in the city center who cannot get to the

honeycombs board pods and hover in specified locations. All citizens are prepared to evacuate to the nearest city via pods in case of a system failure.

The next resource used in LC is regolith. Unlike dust on Earth, shattered rocks on the moon are not weathered down, making them razor-sharp, destroying moving parts, or resulting in injury if inhaled. To solve these problems, Hehehe Inc. harvested all the regolith from the surrounding areas. But before the regolith was turned into building materials, scientists extracted any oxygen through molten salt electrolysis. In this process, molten calcium chloride salt is added to the regolith before running an electrical current through the mixture. The previously unreachable oxygen migrates to an anode where it can be harvested. The oxygen can then mixed with nitrogen and other gases to make breathable air. In addition, molten salt electrolysis makes it easier for any additional resources (precious elements and He_3) to be removed from the regolith. The remaining regolith was then turned into glass or concrete.

The final resource, moon ice, is harvested largely from the permanently shadowed craters at the moon's poles, and is used as water around the city. Water scarcity created the demand for a very efficient recycling system, and water resource engineers complied. In this system, greywater goes through four steps. In flocculation, the first step, solids, fats, and oils are forced into clumps (floc) by a coagulant. After the floc is removed, the water is pumped into a tank and mixed with a ferrofluid made of magnetite powder and vegetable oil recycled from local restaurants. The ferrofluid attaches itself to harmful micro-particles and when it is removed with a magnet, takes the particles with it. In the third stage, the water goes through a sand/carbon filter to remove any remaining pollutants. The water is then disinfected in a process known as corona ozone treatment in the final step. Wastewater is treated the same

way as greywater, except it is first filtered through genetically modified yeasts to remove nitrogen and phosphorus.

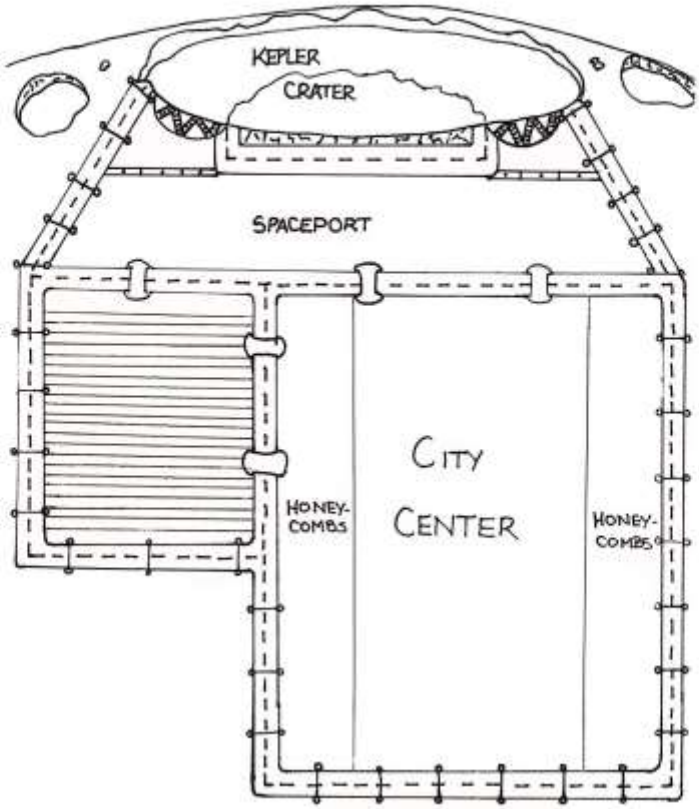

Figure 3: Cutaway diagram of LC

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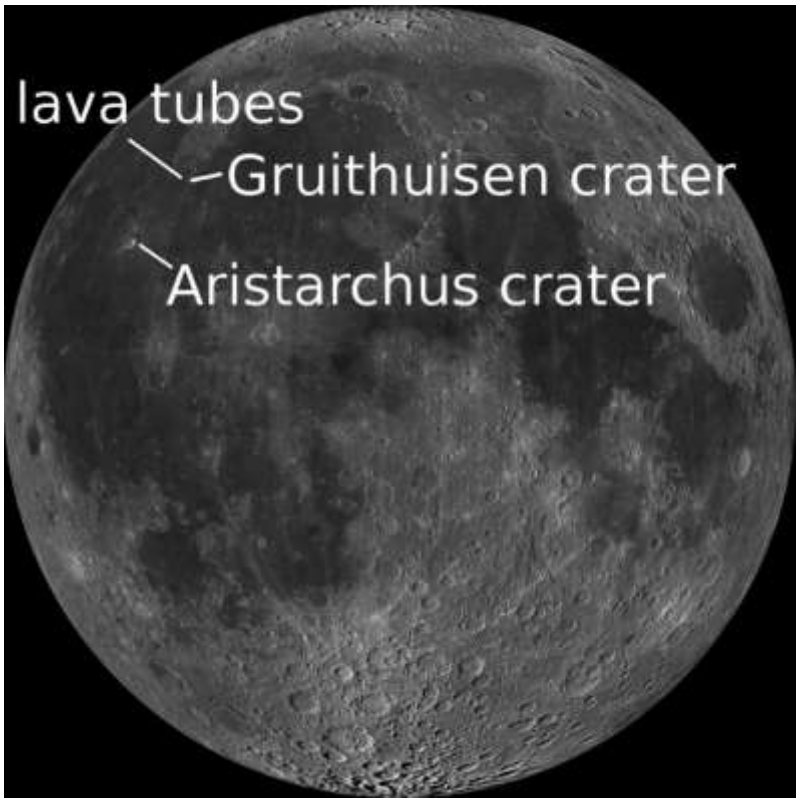
Luna Station Vulcan

Luna Station Vulcan is a city located in the lava tunnels northwest of the Gruithuisen impact crater close to the North Pole of the moon. The rim around the Gruithuisen Crater is relatively smooth and circular, projecting only slightly above the surrounding lunar mare. The interior is relatively featureless with a small floor and mounds of material deposited along the edges of the sloping inner walls. The station has solar powered industrial plants to harvest energy, provide electricity, and process polar ice with algae to get purified drinking water. Lunar greenhouses underground protected from solar flares, cosmic rays, and micro-meteorites help grow kale, leafy greens in hydroponic systems meaning they only need water, not soil to grow. Sunlight from the moon's surface is sent to the plants using light pipes with fiber optic cables and a diffuser.



[Map]

[Entrance to Lava Tubes]

We chose to inhabit the lava tubes to shelter us from meteor bombardment and solar radiation. The lava tubes provide thermal stability with a temperature of around -20°C (-4°F). Having this stable, relatively warm temperature makes building structures and equipment easier, and is a benefit for our city location. One problem with living underground is that it makes it difficult to communicate from one location to another, even between different lava tubes. To overcome this, cables run through the tubes and antennas are located on the surface.

In Luna Station Vulcan, every resident is medically trained to respond to emergencies. Fire is especially dangerous in a closed system. Medical facilities with an emergency room with trained specialists who know how to operate on patients with head injuries, broken bones, and fractured bones or concussions exist onboard. For cases beyond our expertise the station has rapid evacuation shuttles to send critically injured citizens back to Earth to recover, and then they will return when they are ready. Each citizen must also be able to repair their suits and their gear in case they get damaged.

With many specialized systems that still require human oversight there are jobs in water purification systems and delivery, energy technologies, hydroponics agriculture and food

harvest- processing, and sanitation. More experienced candidates will help oversee and manage some of these critical functions. There are specialized jobs openings for search and rescue/security patrols. City services hire teachers, firefighters, librarians, fitness trainers, and communication operators and people who deal with supplies of goods and people to/from Earth. Tourism also helps create jobs like hotel managers, maids, food service people and tour guides. Our city has a population of 750 and will gain about 10 people each 6 months.

Recreational games on the moon in our city are Luna Ball and Hoopers. Luna Ball is a game played by twelve people and the game is like soccer, but the rules are more flexible. In Luna Ball there is one goalie and five players per team, and you use a heavier soccer ball to make goals. You can use the exact same rules as in soccer, but you can use your hands. Hoopers is a game like basketball but you use a heavier ball and you can bounce the ball every five steps or fewer.

Citizens of Luna Station Vulcan live with at least one roommate in a small dome which is about 700 square feet large. The outside of our domes is made from lunar concrete (which is made from regolith and sulfur), and the inside is an inflated living module with an airlock. Transportation infrastructure includes monorails and cable cars which helps overcome lunar dust and rocky surfaces. For power, photovoltaic arrays generate electricity, with solar concentrators providing us heat. Lasers transmit energy from sunlit areas to shadow regions. Solar driven electrolyzers split water into oxygen and hydrogen, which can form propellant or can be recombined in fuel cells for energy at night. We have advanced technologies that enable a reactor to use giant mirrors to channel sunlight onto a furnace a little bigger than an envelope, heating Moon dirt to more than 900 °C until it glows. At that temperature, hydrogen or carbon, brought initially from Earth, can strip oxygen from its minerals and can bind the element together with hydrogen to make water. Another advanced technology is the plastic refabricator which melts plastic waste into a 3D printing filament, which transforms it into new tools for the residents to use in the field of regenerative medicine like to bioprint ligaments and tendons from stem cells, and to fabricate, recycle, and reuse parts and waste materials.

In our city, we have many services such as schools, colleges, hospitals, firefighter stations, search and rescue programs, free cable car and monorail usage, and gyms. Our schools start from Pre-K to 12th grade and after 12th grade you receive your diploma and either go to college and then get a job or directly choose a job. Once a job has been selected, you are an apprentice of trained personnel that currently have the job in which you are interested, and after 5 years of apprenticeship you will receive that job. The firefighter stations will be alert 24/7 in case of emergency fires during the night. We will use our water wisely and scarcely, so we don’t waste it. Our healthcare facilities are free to residents. Our gyms have trainers who make sure that you get a good workout every day to stay healthy and fit, to ensure that there is no damage to your muscles due to the moon’s gravity.

Our city’s innovative tourist center lets you see Neil Armstrong’s footprints and the American flag that he placed. There is a hotel in the 500-foot radius of where the flag and his footprints are so tourists don’t need to step outside. A gift shop inside the hotel has special moon rocks and postcards of different locations on the moon. Tourists can visit these locations using cable cars. Tourists can stay on the moon for two weeks and can step foot outside with the supervision of a guide. Some futuristic elements that we have in our city are hoverboards that can quickly take you places without touching the floor, Artificially Intelligent robots that help with work around the clock, and finally an advanced HVAC unit that can heat/cool to a 100F

differential with respect to ambient temperature to allow habitation in the moon's extreme temperature swings.

Some challenges of living on the moon are solar radiation, communication underground, and especially the lunar dust. We've already overcome the problem of solar radiation because of our location inside the lava tunnels which block it. To overcome the challenge of communication underground, cables would run through the tubes to antennas located on the surface. To solve the challenge of lunar dust, we used an advanced coating on our lunar suits. We have also solved this problem for our transportation, because all our sources of transportation don't touch the ground.

Ice on the moon is mostly in the polar regions. Our city depends on two resources - regolith and ilmenite for oxygen and water. Regolith is found all over the moon's surface and is processed by our ***advanced*** reactor that uses giant mirrors to channel sunlight onto a furnace a little bigger than an envelope, heating Moon dirt to more than 900 °C until it glows. This process can give us water which we then split apart using electrolysis to split apart the hydrogen and oxygen. We condense them for storage. Ilmenite is a good source of oxygen and can be found in the area of the Aristarchus crater. Our innovative reactors can take the Oxygen removed from ilmenite and the hydrogen from regolith and combine them to make water.

[Regolith]

[Ilmenite]

The benefits of using regolith are that you can use it to create water instead of using polar ice. A benefit of using ilmenite is that you can create oxygen and hydrogen. Further easy access to both of our resources poses no risks/tradeoffs, and being top choices, there are no compromises.

Civil, agricultural, mechanical, metallurgical, biomedical, industrial, mining, electrical, and computer engineering are some of the major engineering specialties that are in great demand. Civil engineers help us with major transportation projects like monorails and cable cars. Agricultural engineers solve problems like the storage and processing of agricultural products. Mechanical engineers design industrial machines, refrigeration and air-conditioning systems. Metallurgical engineers develop ways of processing metals and converting them into useful products. Biomedical engineers design instruments, devices, and software used in healthcare. Industrial engineers find ways to eliminate wastefulness in production processes. Mining engineers plan and direct the engineering aspects of locating and extracting minerals on the moon. Electrical engineers work in transport networks, lighting, heating, ventilation, power generation and distribution, renewable energy, manufacturing and construction projects. Computer engineers design and develop computer systems and other technological devices.

As you can see Luna Station Vulcan is a very successful lunar colony and models a city of the ages that is revolutionizing the world!

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SpaceVPN

In 2064, tensions mounted between Russia and North Korea, leading people to fear an eventual cold war. The EU knew they needed to step in before it was too late. North Korea took this as a threat and started their invasions, beginning with Russia. The cold war everyone feared had begun. In return, on December 3rd, 2066, Russia dropped a bomb on North Korea. South Korea and China were impacted by the nuclear fallout and both declared war on Russia in 2067. Within three years, it was a full-blown world war. Countries came together to bring the populations safety onto the moon. Now it's 2133 and our lunar city, SpaceVPN (virtual private network) is thriving. Space VPN is located on Mare Humorum LAC 93 because it has flat terrain and smaller craters within which we built our residential areas. A trade-off of choosing this location was that the large rocks around the area make it difficult to get to the water sources.

Living in a Lunar Colony

Our city has a population of 33,465 with a median age of 43, most of these citizens work in the chemical engineering field. When our residents are not colliding electrons with a particle accelerator, they enjoy playing video games and competing in indoor sports. Most citizens live in our volcanic glass domes made within small craters. This design was chosen as solar panels can be placed on top of the roof to supply energy and protect against solar radiation. We were also lucky to find Regolith which is hard geological material. This helps our buildings as we can put it over the volcanic glass to make it stronger and to protect from solar radiation. As our

population grew and citizens had children we needed to add to our educational systems. We started with universities then expanded the program by adding elementary, middle and eventually high schools. Our first graduating class will happen next year. We are so excited. We

eat 3d-printed food. 3d printing food is tasty but unfortunately it is a little less healthy and can cost quite a bit. Health and protection are of the utmost importance. We have multiple healthcare facilities, innovative drones that can go to places a human can't, state of the art facilities with nanotechnology, and AI technology. One of our newest additions is our capability to text using the brain that our neurosurgeons have worked very hard on. We have two transportation systems that are both powered by solar energy, one personal and one public. To power these systems we use solar energy. To protect against anti-gravity, they are both placed underground where our space engineers have created artificial gravity. Most citizens find our nanotechnology and hover trains that float to be the greatest features in our lunar colony.

Even with these wonderful aspects within our city, residents still miss home. The challenges we have seen the most are going outside and smelling fresh air. To resolve this we made a giant indoor ecosystem to replace the Earthy feeling. When building this colony we needed to look at the potential

hazards and risks. No gravity and solar radiation were the most pressing and needed the most attention as it can create diseases like cancer and weaken the bones.

Lunar Resources

Regolith

Regolith is the surface of loose hard rock that is found on top of the soil. Employees pick this resource up using little cranes and put it on trucks to transport them to the conversion facilities where SpaceVPN's civil engineers work on making that into building material. SpaceVPN uses these rocks to cover the volcanic glass. This helps protect citizens and crops from solar radiation. Solar radiation is dangerous for your health and raises your chances of getting cancer. When we decided to put regolith over the volcanic glass it made a tremendous difference to the protection of our citizens. A tradeoff is that the light will have to be artificial, but the overall health of everyone is worth this energy.

Volcanic Glass

Volcanic glass is any sort of rock made from lava or magma that has a chemical composition very close to granite. This can be found on the Taurus Littrow valley and, while it may be a little far away from our base, we are able to send crews there for short periods of time to pick this resource up from the lunar soil. Then we can put regolith over it and put it on the

little craters to make homes. Teams of glaziers, our citizens who have attended trade schools for manufacturing glass products and structures helped make round volcanic glass to put as domes.

Silicon

Silicon is found on the Moon as miniscule rocks on the lunar surface. Workers divide the soil and silicon, then transport the silicon to our base for usage in our solar panel manufacturing. We quickly realized that if SpaceVPN was to continue taking up lunar soil, the ground would be weakened. Geotechnical engineers have been trained to work with lunar resources and identify the best places to locate silicon with the least risk.

Conclusion

With the help of many engineers and scientists, SpaceVPN is a safe place to live. The artificial gravity that we were able to create with space engineers and our high-tech features throughout our city help citizens feel more at home. Our domes are covered with Regolith so it can be protected from the solar radiation so our citizens are protected from too much exposure and the possibility of getting cancer. The decision to 3D print food is one of the most important elements for our colony in space, this helps everyone have a healthy diet to live longer. With all of these features people no longer miss earth and are happy to live in this lunar colony.

Word Count: **967**

Image Count: **4**

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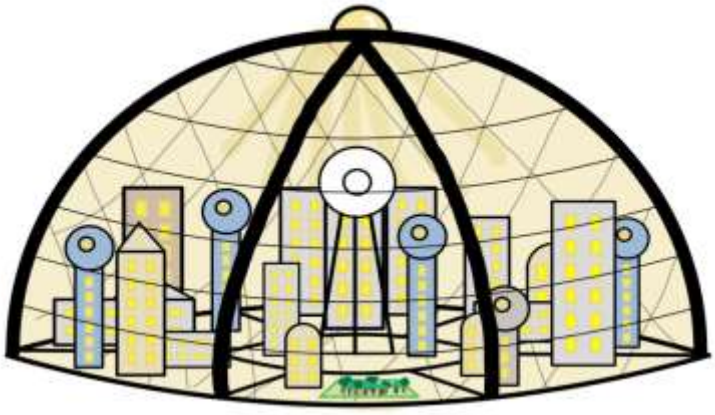
Tennomiyako - The Colony of the Heavens

With the advent of new technologies in the 22nd century, humans started to establish the first lunar colonies. The early 2100s were an era of unprecedented lunar exploration. Now, in the year 2151, the Japanese lunar colony of Tennomiyako, Colony of the Heavens, is at the forefront of innovation and has a diverse population of 10,000. Originally a scientific outpost, it has grown to become an economic powerhouse. The colony consists of 3 domes, a space elevator, and lunar mines. Its economy is formed by exporting precious metals, electronics, and space-research and development.

Tennomiyako is located in the Shackleton Crater on the lunar South Pole. The crater is 19 kilometers wide and 3 kilometers deep, giving the colony large amounts of space. Because it is located in the South Pole, the interior of the crater is in eternal darkness. This means that water that arrives there will freeze and be stored there as ice. Thus, about 22% of the crater's surface area is composed of ice.[1] However, the rims of the crater receive sunlight for most of the lunar year, with only a few days of darkness.[2] These characteristics of the Shackleton Crater make it the optimal location for a settlement.



The 3 domes that make up the central portion of Tennomiyako are where citizens live and work, with 1 larger dome and 2 smaller ones. These domes make life possible on the Moon, as they protect citizens from the surface's inhospitable conditions. The larger dome is where citizens live and work in healthcare, safety, education, tourism, mining, etc. One of the smaller domes is where mined materials are processed and manufactured, and the other dome is where the colony's food is grown. For recreation, citizens enjoy Tennomiyako's extensive parks, low-gravity sports, and tourist attractions to maintain their mental well-being.

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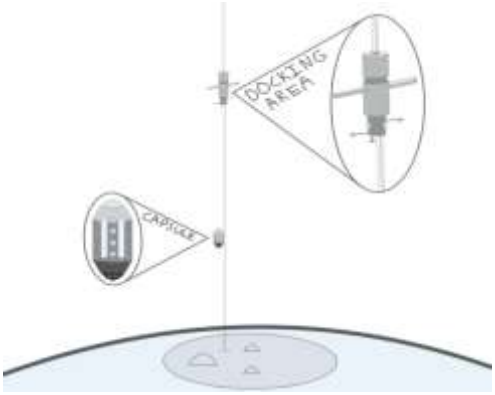
[1] Choi, Charles Q. "Huge Moon Crater's Water Ice Supply Revealed." *Space.com*, Space, 20 June 2012, www.space.com/16222-Moon-water-ice-shackleton-crater.html.

[2] Speyerer, Emerson J., and Mark S. Robinson. "Persistently Illuminated Regions at the Lunar Poles: Ideal Sites for Future Exploration." *Icarus*, vol. 222, no. 1, 2013, pp. 122–136., doi:10.1016/j.icarus.2012.10.010.

The housing infrastructure consists of 6 pillars curved toward the center of the dome, a transparent 3-layer wall, and a geodesic triangle frame that runs through that wall. Within the pillars and frame are vents, atmosphere regulators, and sensors that ensure the atmosphere is satisfactory.

The outer and inner layers of the 3-layer wall are made of polycarbonate and aero-gel composite material giving it strength, rigidity, and extreme-temperature resistance. These two layers serve as a redundant safety measure. The middle layers are a combination of noble gases due to their insulative properties.

The domes are divided into multiple sections, with walls similar to the outer dome-walls between each section. Each segment has its own life-support systems. These segments are important, because if there is a fire, rupture, or system failure in one section, then it can be evacuated and sealed off.



To move people and goods, there is a robust transportation infrastructure in Tennomiyako. One of the main transportation infrastructures is a space elevator consisting of a 60,000 kilometer long kevlar-composite tether and multiple capsules. The capsules travel from a base at the surface-level to the docking area at the top. Avoiding launching up saves fuel. The docking area is also kept in equilibrium.[3]

Inside the colony, connecting the domes, space elevators, and mines are a series of underground tunnels with electromagnetic railways. Individual vehicles are used to ride the railways, and when someone wishes to travel they would first enter a tunnel through an above-ground entrance before calling one of the vehicles. It would then bring them to their desired destination at speeds of 150 kilometers per hour.

One of the most iconic infrastructures of Tennomiyako is its artificial gravity simulator. The low gravity of the moon, while energy-efficient for transportation due to reduced friction, can be uncomfortable for some citizens. To manage the risks and benefits, the engineers of Tennomiyako designed an electromagnetic gravity simulator using an underground amplified electromagnetic field generator (AEFG). Citizens can sew magnetic materials into their clothes, pulling them down and replicating Earth's gravity.

City services include education, healthcare and protection against fires, moonquakes, and meteors.

Living on the Moon comes with negative effects such as muscle and bone shrinkage.[4] To prevent these medical problems, healthcare services ensure citizens exercise daily and maintain a healthy diet. Tennomiyako has a variety of parks and recreation to fulfill these requirements

[3] Gupta, Rohit. "Is There Gravity in the Space Station?" Brilliant Math & Science Wiki, brilliant.org/wiki/is-there-gravity-in-the-space-station/.

[4] Johnson, Michael. "Bone and Muscle Loss in Microgravity." *NASA*, NASA, 7 Jan. 2020, www.nasa.gov/mission_pages/station/research/station-science-101/bone-muscle-loss-in-microgravity/.

from low-gravity sports to gyms and parks. Citizens are also screened often by advanced AI to check for medical issues. Also, 3D printers are used to print organs and medicines.

Education services overhauled the traditional school system in favor of a system more suited to the future. Each student learns best in a different way, and to ensure that, each student is assigned a personalized learning plan. Also, using the help of AI and VR, Tennomiyako revolutionized its education system.

Tennomiyako has extensive protections for its residents against lunar hazards.

Fires are one of the colony's largest threats, and so it has an extensive fire-fighting system. If there is a large fire in any section, the people inside are evacuated and the oxygen within the section is removed. However, small fires are put out by small drones and machines within buildings.

Moonquakes pose a large threat to Tennomiyako. They can collapse tunnels and buildings. To combat this, Tennomiyako has a futuristic moonquake repeller. It emits waves that weaken oncoming moonquakes. There are also dampeners and evacuation plans.

Meteor strikes are also more common on the Moon. To combat this, the colony has multiple futuristic laser cannons around the rim of the crater that destroy the meteors. The cannons create powerful compact rays by capturing sunlight and using energy to excite electrons inside. They focus on the meteors and break them into pieces spacecrafts can then collect.

To save costs, natural resource engineers found ways to use lunar resources like sunlight, a primary component of Tennomiyako's energy production infrastructure, and regolith, which is fundamental to its economy, atmosphere, and construction.

The rim of the Shackleton Crater receives sunlight for the majority of the lunar year, allowing solar panels on the rim to collect enough energy to satisfy Tennomiyako's needs. Sunlight is also used to power Tennomiyako's meteor-defense lasers.

Furthermore, sunlight is used for lighting and heating the domes. Because Tennomiyako is located inside the Shackleton Crater, it is in permanent darkness, requiring lighting and heating. To combat this, mirrors on the rim reflect sunlight to "artificial suns" on top of each dome. The artificial suns then diffuse the sunlight over their respective domes. Because the light is focused on the artificial suns, they become extremely hot. Air is fed through the artificial suns using pipes, and then comes out of vents located around each dome. One tradeoff of using mirrors and solar panels on the rim is that because they are so far away, if an issue arose it would be difficult to travel out and repair it.

Metals such as iron, silicon, and titanium are found in the regolith and are mined profitably with drills and robots. Silicon, for instance, is 20% of the regolith's weight and is an essential component of producing solar cells and semiconductor devices.[5]

Tennomiyako also utilizes the regolith in other ways, such as in its artificial atmosphere. It consists of a mixture of 79% helium and 21% oxygen, called heliox. Heliox is easier to

[5] Crawford, Ian A. "Lunar Resources: A Review." *ArXiv.org*, 25 Oct. 2014, arxiv.org/abs/1410.6865.

breathe than Earth's atmosphere because it's less dense.[6] Both helium and oxygen are found inside the regolith and can be extracted. While it is expensive to extract gases from regolith, once extracted, the atmosphere is reused through plants and oxygen recirculation.

The primary construction materials in Tennomiyako are also made from regolith. Concrete is formed by crushing up regolith and combining it with a geopolymer cement made from minerals on the Moon. This material is extremely resilient and is used in the domes' pillars, buildings, underground tunnels, and other structures.

Tennomiyako wouldn't be here without its engineers. Civil and mechanical engineers built the city's framework, and machinery, and designed the systems, processes and infrastructure that allow the city to run. Mining engineers made sure the mining process was effective by finding the areas with the most resources and making mining profitable and efficient.

With the help of mining and mechanical engineers, Tennomiyako developed an automated fleet of robotic miners. They use many technologies including lasers, magnetic field generators, and even weight-changers. Weight-changers use the mass-energy equivalence to change a miner's weight when needed to accelerate or stay at rest. Other futuristic technologies used throughout Tennomiyako include its moonquake repeller, laser cannon, space elevator, dome walls, and AEFG.

Unfortunately, the engineers made some tradeoffs for Tennomiyako's advancements. Agricultural engineers developed plants that grow efficiently, are energy-dense, and serve multiple purposes. Because many types of plants and all livestock do not meet the intense standards, there is a lack of variety in the citizen's diet. Another tradeoff is that despite the AEFG keeping citizens' health safe, it feels different from Earth's gravity. Although citizens will get used to it, it is slightly uncomfortable for tourists and new inhabitants.

With all of these futuristic technologies, Tennomiyako is a true beacon of innovation.

Word Count: 1497

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