SpaceOps-2023, ID # 152

HORA, a Moon habitat mission

Alexandra-Maria Titel[a]*, Amalia Nicole Teodorescu[b], Alexandra-Maria Miron[c], Ileana Rebeca Crăciun[d]

[a] *"Andrei Şaguna" National College, Şirul Andrei Şaguna Nr. 1 Street, Braşov City, Braşov County, Romania 500123, alexandra.titel@saguna.ro*
[b] *"Andrei Şaguna" National College, Şirul Andrei Şaguna Nr. 1 Street, Braşov City, Braşov County, Romania 500123, amalia.teodorescu@saguna.ro*
[c] *"Andrei Şaguna" National College, Şirul Andrei Şaguna Nr. 1 Street, Braşov City, Braşov County, Romania 500123, alexandra.miron @saguna.ro*
[d] *"Andrei Şaguna" National College, Şirul Andrei Şaguna Nr. 1 Street, Braşov City, Braşov County, Romania 500123, ileana.craciun@saguna.ro*
* Corresponding Author

Abstract

During the past 50 years, not only did human civilization evolve by exploring Earth's mysteries and finding solutions to modern problems, but also discovered ways of leaving Terra in order to investigate the pure unknown: space. The human kind made great improvements in the field of astronautics so that now we are able to explore space further than simply looking through a telescope, but traveling and analysing from close up. Nevertheless, we still find ourselves at the beginning of this grand and unpredictable journey that will at some point definitely change our lives forever.

This project introduces a special 3D model of a moon habitat, which will be located underneath the Moon's surface, in one of the lunar tubes situated near the Shackleton Crater, right at the South Pole of this natural satellite, in the permanent presence of sunlight. The benefits of such emplacement are the protection against space radiation, meteorites, other bodies or phenomenon, and against extreme temperatures (on the surface ranging between - 173°C and 100°C, whereas inside the lunar tubes remaining at a constant temperature of approximately -23°C), to name a few. The many harms listed above that could have potentially affected the wellbeing of the camp determined us to consider the placement of the camp inside the lunar tubes a necessity. The purpose of this project is to stretch the borders of the current knowledge about the Moon by becoming a research base and making deeper investigations of the lunar tubes from which we hope to extract valuable data. We've made it our mission to research the moon's environment and present it to every person, as many individuals still don't know enough about the Moon and its harsh environment. Through this project we attempt to prove the fact that it is possible to create a habitat that can sustain human life, independent from the one on Earth. Lastly, it is important to mention that this base also serves leisure purposes, such as the creation of the first lunar hotel and the development of the new industry of space tourism.

To conclude, several different concepts have been evaluated and the most reasonable was chosen for a detailed design. In spite of the fact that lunar construction is difficult, the proposed habitat promises to resist the Moon's harsh environment and sustain life.

Keywords : *Moon, habitat, Lunar tube, Shackleton Crater*

Acronyms/Abbreviations

Active Thermal Control System – ATCS
Multi-Layer Insulation – MLI
Passive Thermal Control Systems – PTCS

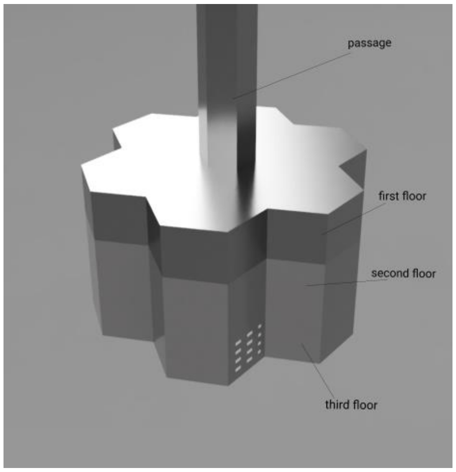
1. Introduction

Space exploration is crucial as it provides us with valuable insights about the history of our solar system and the geologic record of Earth. The primary objective of our Moon Camp is to study the lunar lava tubes in order to create a comprehensive map of their network. These tubes are formed by the eruption of basaltic lava flows on the Moon, which cool and harden on the surface while allowing the lava to flow beneath in a tube-like conduit. Once the flow stops, it leaves behind a hollow void, creating a lunar lava tube. These tubes have the potential to provide protection for astronauts from cosmic and solar radiation impacts, and extreme temperature variations between the lunar day and night. Scientists believe that some of the tubes may be interconnected, forming an underground maze containing valuable resources such as ice. Additionally, the Hora lunar camp is designed to be visitor-friendly, with the first floor dedicated to tourism.

2. Layout and calculations

2.1. Structure:

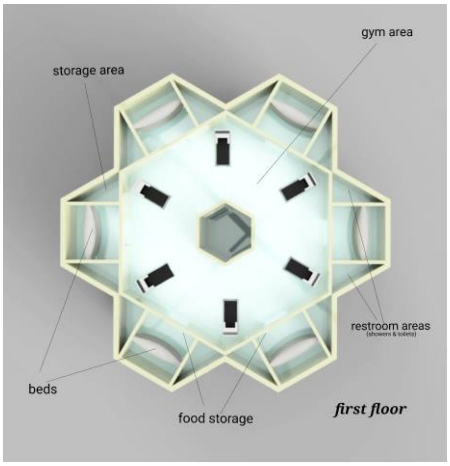
Hora is designed to have an accommodation space for twelve people, scientists or tourists, sufficient storage space for fuel, water, food, for oxygen's obtainment and a research laboratory. All these are separated into three different floors of the same size, but slightly different in spacing.

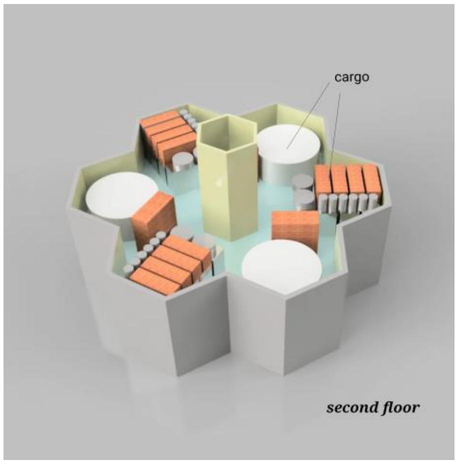


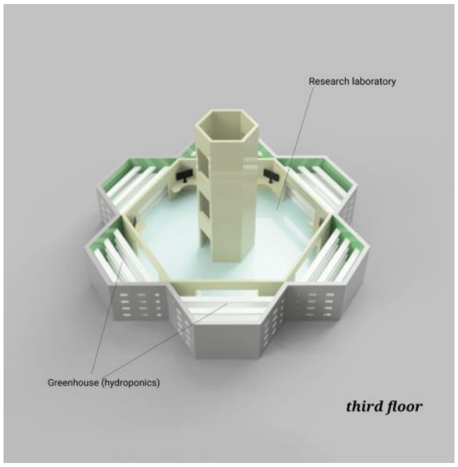
The integral moon habitat, observed from above, traces the contour of six hexagons encircling a centre one, all equal in size, mimicking a honeycomb. One hexagon's edge is 4 m. Conclusively, the surface of one floor is 250 m^2, from which 10 m^2 are subtracted for the elevator. In total, Hora presents a 720 m^2 surface, distributed on all three floors, each 3 m in height.

The first floor presents a more complex arrangement than the others. Through the top view, it can be observed how walls are splitting the room into multiple chambers of 17 m^2. Furthermore, two retractable doors divide the chambers into three spaces, a rectangular 11 m^2 surface for the bunk beds and two triangular 3.5 m^2 spaces designed for the bathroom and for personal belongings.

The dimensions have been chosen in order to optimize the use of the rather tight space given, while still meeting the scientists' and visitors' needs.







2.2. Moon Camp protection system:

Environmental conditions outside the spacecraft are cruel, meaning that an active shield should be used in order to control the heat (18 - 26°C), humidity (40-60%) and prevent people from space radiation.

As space air does not exist nor do conduction or convection, thus the only way of keeping the temperature at a specific level is by using already existing radiation. The habitat is therefore insulated.

In order to keep these parameters under control, an extensive thermoregulatory system, including both PTCS as well as ATCS which cover the habitat. Both serve multiple functions such as protecting the base from overheating and low temperatures.

One of the used PTCS is the highly-reflective blanket, MLI, used to keep the solar radiation that comes from the top of the base out while also preventing the cold from entering the metal structure of the base. A fluid loop is used to transfer the heat emitted by equipment to the radiators, in order to reduce the temperature inside the ship and maintain the level of humidity.

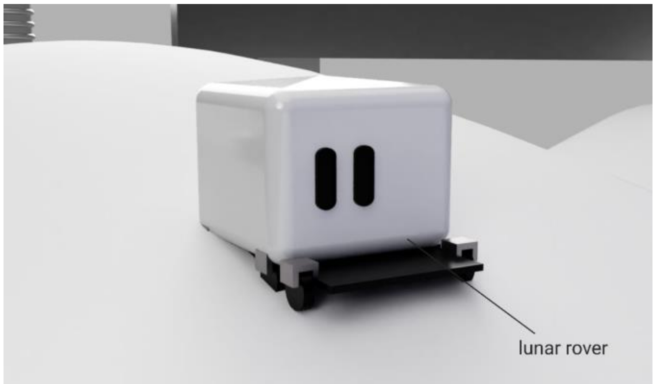
3. Location

When determining the location for our base, several factors must be taken into account such as accessibility, ease of construction, and protection from external conditions. The chosen location for the Hora Camp is the Shackleton Crater at the Moon's South Pole as it is one of the few places that offers constant access to sunlight, which is beneficial for our mission on the lunar surface. The camp is situated underground, providing a simple yet effective way to shield the explorers from harsh conditions such as extreme temperatures and radiation. Additionally, our objective is to create a detailed map of the lunar tubes, and being situated close to the area of study provides aid in advancing our understanding of space.

4. Life support

4.1. Water

At the beginning of the habitat's construction, water is initially brought from Earth. However, after the Moon Camp is set up, the water is obtained from the lunar ice (located at the South Pole, near our location) [3] by heating the ilmenite (an oxide of iron and titanium, a common mineral on the moon) to around 1,000°C with hydrogen which reduces it to water, iron metal and titanium oxide. The water is mined from the bottom of the Shackleton Crater. It is then stored and filtered through a water purifier with the waste liquids from the astronauts. A closed water cycle system is thus formed.



As demonstrated [1], humans need on average 133 liters of water every day which includes the water used for personal hygiene, consumption and cooking. [2] Moreover,the maximum amount of water the 170 hydroponics used on the third floor can consume is 121 liters a day. However, this highly depends on the size and type of plants grown at a current moment. Therefore, the maximum consumption of water needed on Hora is 1717 liters per day but could go as low as 1250 liters.

4.2. Air

Initially, compressed air is imported from Earth in order to sustain the early stages of the moon camp's set up, but upon the finalization of the construction, oxygen is obtained from the plants in the greenhouse.

The plant usage method, presented in the study „Effects of Rising Atmospheric Concentrations of Carbon Dioxide on Plants" [4], paved the pathway on developing a system to enhance oxygen production and more. This showed that plants grow bigger, faster, produce more oxygen and consume less water in an environment with a higher CO_2 concentration level, which also boosts food production.

The plant types with C_3 photosynthesis [5] maximize the benefits of a higher CO_2 concentration in their environment, presenting all the behaviors mentioned above. CO_2 levels elevated from 475 to 600 ppm show a 40% rise in photosynthetic rates, and a decrease in stomatal conductance of water, resulting in a reduced use of water of 5 – 20%. That combined with nitrogen richer soil, the growth and photosynthesis enhancement of the plant will not be as limited by the mineral availability and because C_3 photosynthesis plants are mainly legumes.

Moreover, C_3 photosynthesis has light-independent reactions, meaning that they continue the photosynthetic process regardless of the amount of light. That means considerable decreases in energy consumption. Regardless of the fact that they are light-independent, photosynthesis in plants is encouraged by the spectrum between blue (425nm – 450nm) and red(600nm – 700nm) light. That is because the light outside that spectrum are not used by plants, as these contribute to heat 32 building up in the plant's tissue, which causes damage and interferes with the process of photosynthesis [6]. Therefore, the LED plant light bulbs [7] are used in the greenhouse. This way, plants become a very stable resource for the oxygen needed by HORA's inhabitants

This solution guarantees the 20.947% of oxygen required for a healthy atmosphere and also shields the inhabitants from CO_2 poisoning. The Faraday electro-swing reactive adsorption for CO_2 [8] is utilized to redirect the CO_2 from the living spaces to the greenhouse. It can capture „CO_2 both in a sealed chamber and in an adsorption bed from inlet streams of CO_2 concentrations as low as 0.6% (6000 ppm) and up to 10%, at a constant CO_2 capacity with a faradaic efficiency of >90%, and a work of 40–90 kJ/mole of CO_2 captured, with great durability of electrochemical cells showing <30% loss of capacity after 7000 cycles." – [8]. If the CO_2 concentrations become detrimentally high even for the plants, CO_2 scrubbers will eliminate that.

The habitat has a volume of approximately 2,250 m^3, of which 78% is nitrogen (which isn't consumed during the breathing process) and the remaining rest is 21% oxygen, which is 472.5 m^3. Knowing that the tidal volume of human lungs is 400/500 ml and the normal respiration rate is 12 to 20 breaths per minute [9], that means 6 to 10 liters are inhaled and exhaled. That makes 8,640 to 14,400 in a day, from which 21% is oxygen - 1.8 to 3 cubic/ person/ liter. Multiplying that by twelve people the results are at least 36 m^3 totally in a day. That 472.5 m^3 could suffice 12 inhabitants for about 13 days. This is beneficial because it allows for emergency transport of compressed air from Earth to the Moon, which only takes 3 days [10]. However, this would not be necessary due to the constant oxygen support provided by 5000 plants.

4.3. Food

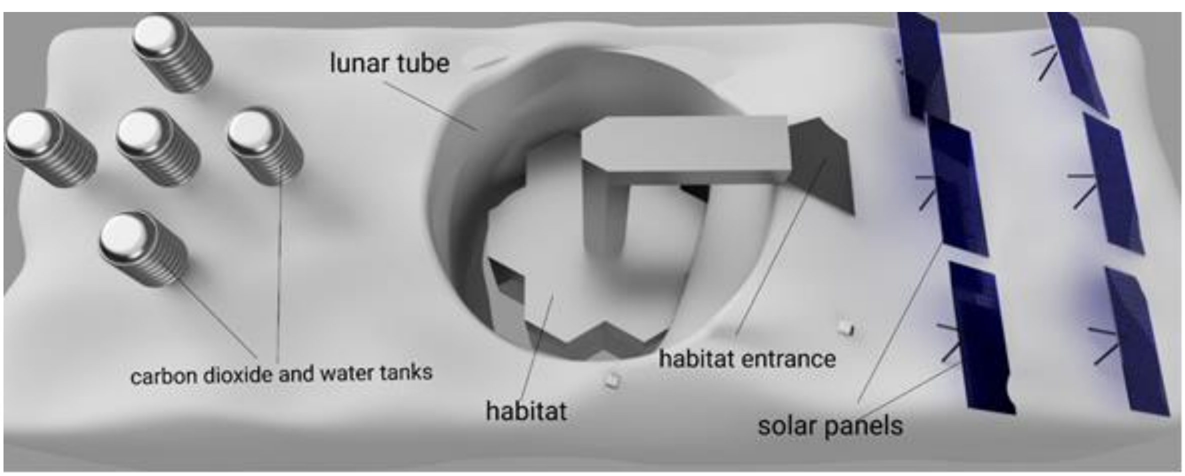
In the first phase the food is transported from Earth with the help of the SpaceX Dragon that is connected to the Gateway. From there, a commercial lunar lander brings the food to the base. In the next phase plants are grown in the greenhouse (located on the 3rd floor). The plants are part hydroponics, as they use less water than traditional soil-based systems and need no soil, part C_3 photosynthesis plants. The pants are watered through an irrigation system which delivers water, CO_2 and nutrients to the plants. The three meals served at the cafeteria have the role to compensate for possible deficiencies such as vitamin D, vitamin K and vitamin C and satiating food such as nuts and other protein edibles.

4.4. Power

The location near the Shackleton Crater, allows constant access to sunlight. Therefore, we use solar panels in order to produce power. A solar tracker is used in order to maximize the amount of energy produced. The power is stored in high-capacity batteries as a backup source during possible outages.

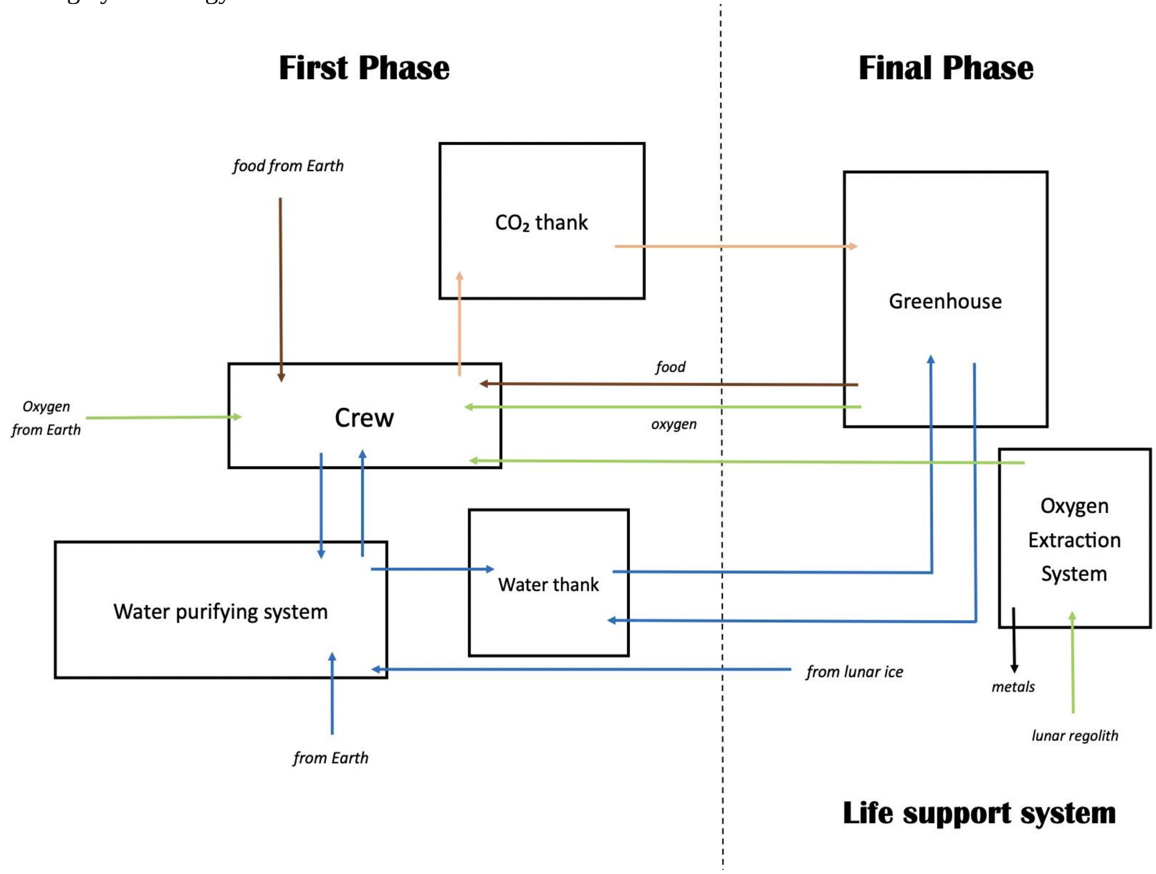
Furthermore, Hora uses Thermoelectric Generators that convert the big temperature differences on the Moon directly into electrical energy through a phenomenon called the Seebeck effect.

In order to keep a 21-22° Celsius temperature inside our moon habitat, we also use a Moondust heater. A



moondust heater is a system that uses solar concentrators to store the energy in the lunar soil during the day, releasing it during the night. The concept of this system is based on mirrors that direct the sunlight into processed lunar regolith, into which a heat engine would be placed, as shown [11].

This engine is powered by the temperature difference between the lunar day and night. As mentioned in source [11] and [12], the heater would be kept running by the Sun's heat during the day,when the sunlit surface temperatures soar beyond 100° C while also storing extra heat in the soil. In the night time, the heat engine would be kept running by the energy released from the heated soil.



5. Discussion: Mapping process

The most important feature of life in the Hora moon camp are the underground explorations with the all view 360 camera. While scientists are limited in terms of the amount of time they can spend outside the habitat the camera isn't. Therefore, it can travel the longest darkest distances, scanning the underground tunnels and retrieving the data to the scientist to analyse and to put in rendering software in order to make accurate maps of the underground world.

6. Conclusions

6.1. Layout and calculations

Hora, is shaped as a honeycomb, having a total surface of 750 m^2 and height of 11 m, and 250 m^2 on each of the three floors of 3 m height. It is located inside the lunar tube. The habitat's infrastructure consists of a combination of titanium, magnesium alloys, Kevlar, high-grade steel and carbon nanotubes.

MLI is used to maintain the heat inside the habitat. In order to reduce the temperature (if needed) and keep the level of humidity from altering, we use a fluid loop.

6.2. Location

Hora Camp is located in the Shackleton Crater at the Moon's South Pole as it offers constant access to sunlight. The camp is situated underground, shielding the explorers from harsh conditions (temperatures and radiation).

6.3. Life support

Water will be extracted from the lunar ice from the bottom of the Shackleton Crater and filtered afterwards with a water purifier.

Hora's 3rd floor will be dedicated to the food production system based on growing C_3 plants and hydroponics as they use less water and need little soil.

Solar trackers placed near the Shackleton Crater will be providing the settlement with a constant source of sunlight which will be partially stored in high-capacity batteries as a backup for during outages. Another power source is the Thermoelectric Generator.

Initially, compressed air will be imported from Earth in order to sustain the early stages of the moon camp's set up, but upon the finalization of the construction, oxygen is obtained from the plants in the greenhouse.

6.4. Discussion: Mapping process

The astronauts go on routine explorations and rovers are constantly scanning the underground tunnels in order to make an accurate representation of them.

References

List of references

[1] Instituto Nacional de Estadistica, Survey on Water Supply and Sewerage. Year 2020 https://www.ine.es/dyngs/INEbase/en/operacion.htm?c=Estadistica_C&cid=1254736176834&menu=ultiDatos&idp=1254735976602 (accessed 28.01.2023)
[2] We grow hydroponics, Plant spacing https://wegrowhydro.com/plant-spacing/ (accessed 28.01.2023)
[3] ZDNET, Rockets to mine water from the moon https://www.zdnet.com/article/plans-to-rocket-mine-water-from-the-moon/ (accessed 28.01.2023)
[4] Effects of Rising Atmospheric Concentrations of Carbon Dioxide on Plants https://www.nature.com/scitable/knowledge/library/effects-of-rising-atmospheric-concentrations-of-carbon-13254108/ (accessed 20.11.2022)
[5] C3 plants C3, C4, and CAM plants (article) | Khan Academy (accessed 20.11.2022)
[6] Best light sources for plants What Are the Best Light Sources For Photosynthesis? - Vernier (accessed 20.11.2022)
[7] Best light absorption spectrums ap13_biology_q2 (collegeboard.org) (accessed 20.11.2022)
[8] Faradaic electro-swing reactive adsorption for CO2 capture https://pubs.rsc.org/en/content/articlelanding/2019/ee/c9ee02412c (accessed 28.07.2022)
[9] Lung volumes https://en.wikipedia.org/wiki/Lung_volumes (accessed 01.08.2022)

[10] Length of journey from Earth to the moon https://moon.nasa.gov/resources/47/journey-to-the-moon/ (accessed 017.08.2022)
[11] Science direct, Heat storage and electricity generation in the Moon during the lunar night, https://www.sciencedirect.com/science/article/abs/pii/S0094576513002567 (accessed 01.08.2022)
[12]The engineer Moondust heater could keep astronauts warm on the lunar surface, https://www.theengineer.co.uk/content/news/moondust-heater-could-keep-astronauts-warm-on-the-lunar-surface/(accessed 04.11.2022)