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SOLENOID MOON-BASE CONCEPT

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Our research deal with the design of an innovative system that could protect a hypothetic moon base from solar rays and micrometeorites, while living it enclosed in a transparent shell, without stopping the view of the celestial vault. This is possible by placing the base within the circular section of a toroid consisting of a series of high voltage cables, inside which the magnetic field is null, while outside is enough strong to protect the base from the radiation. The same wiring of cables act as a load-bearing structure for the solid shield that protect from micrometeorites impact.

I. Introduction

THE debate on the human colonization of other worlds is more alive than ever and the preparation of the trip to Mars is now in a state of great advancement. Creating an outpost on the moon is believed to be necessary for future missions and, if anything, to exploit the materials on our satellite. However, we know that moving away from our planet for long periods involves exposure to great risks and to a series of problems that in the case of a permanent colony become infinitely bigger than what has been already solved for the small space travels that has been done until today.

Problems are many, they range from physical to psychological aspects that often are joint together, and it is not here the place to develop them all. We have started to try to reduce the phenomenon of disorientation and discomfort that man can feel in case of detachment from Mother Earth for a long time; an anxiety that, for long periods, as a human colony must be able to allow, can lead to depressive and hallucinatory reactions until the suicide, according to some psychology studies.

Therefore, in this study, we tried to reduce this effect as much as possible by designing the future lunar base (or similarly the outpost on Mars that presents the same problems) making it as open as possible to the surrounding space, to the lunar landscape and to the view of the Earth, as to create comfort for the inhabitants who might feel closer to her.

However, to do this, we run into two, among others, major problems: cosmic radiations and micrometeorites, which are the main subject of our research. In fact, our study essentially focuses on the transparent shell and on the outdoor habitat near the pressurized base, where human can safely walk on the lunar surface protected from harmful radiation and, at the same time, without having to live buried under a huge layer of regolith.

II. The problem of cosmic radiations

The average radiation dose to which a human being is exposed in a year living on Earth is about 3.6 milliSieverts (mSv). People employed in particular radioactive industrial activities may be exposed to a maximum of 50mSv per year, while for astronauts we have a maximum of 500 mSv per year or 2000-4000 mSv (depending on age and gender) over the whole lifetime. These values are expected to cause no more than a 3% increased risk of developing cancer, which NASA and the astronaut corps considers acceptable.

For a moon settler the acceptable limit would depend on how long he stops in the lunar base but an indicative value would be about 740 mSv per year. Indexing this value according to the minimum quantity to which a terrestrial is subjected (as said, about 50mSv) it is obtained that about 8cm of titanium, 17 cm of aluminum, 60cm of water or 52 m of humid air at 1m pressure would be required to protect the lunar base.[1]

Generally, in most of the projects we have seen over the years, it is proposed to protect the human base with a considerable layer of lunar (or Martian) regolith of about 5/7 meters thick. Considering smaller thicknesses of these materials means subjecting residents to higher radiation levels with higher risk of contracting tumors. Moreover,

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levels of radiation in space are not constant over time, but vary for example in case of solar storms. In this case, many projects proposed to set up a safe emergency area to protect the inhabitants during these events.

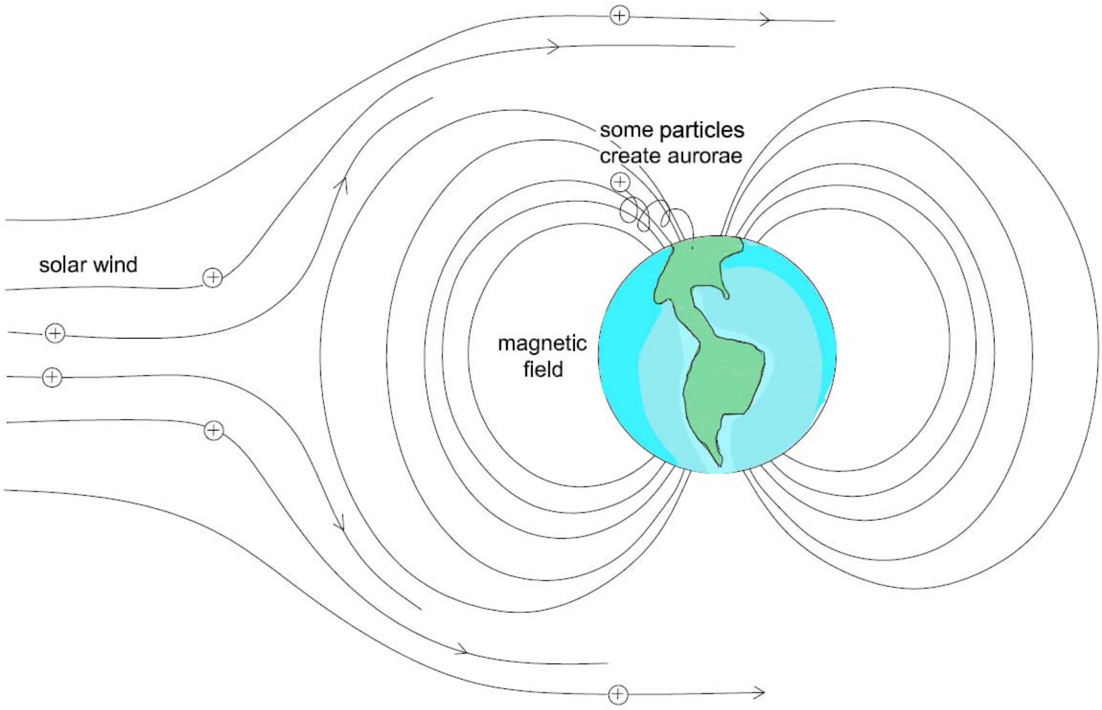

Figure 1. The terrestrial magnetic field protect the Earth from solar wind

Alternatively, the base could be built within so-called "lava tubes" that are natural cavities or deep tunnels in the lunar subsoil. They can have a diameter of 300m and a depth of about 40m below the basalt layer; in addition to protecting the base from cosmic radiation, they also protect it from meteorites and micrometeorites. Inside these cavities, the temperature would remain stable at about -20 C° instead of varying outside from -173 C° up to + 100 C°. “Lava tubes” on Mars are estimated to have about 30m of basalt cover.

Nevertheless, the common topic behind all these systems of protection is a great material mass, which protect the inhabitants, paying the possibility to see lunar landscapes and celestial vault, living buried in the dark under a protective layer!

III. The protection system with artificial magnetic fields

Designed for long interplanetary trips, electromagnetic fields can also effectively protect against cosmic radiation. Already Werner von Braun designed a hypothetical starship enveloped with a solenoid electric current path, and the idea was then pursued until the recent studies carried on by Roberto Battiston, director of ASI and professor of theoretical physics at the University of Trento. With a superconducting solenoid or toroid that surrounds the spacecraft, an electromagnetic field reproduces the Earth's surface and protects the crew from radiation. Superconducting would allow the power to flow along the cables without resistance, minimizing the energy waste, so that a few dozen kilowatts could be enough to supply the magnetic field. Since the temperatures necessary to create superconductivity are near the absolute zero, it is necessary to provide cables protection and proper insulation to maintain such low temperatures.

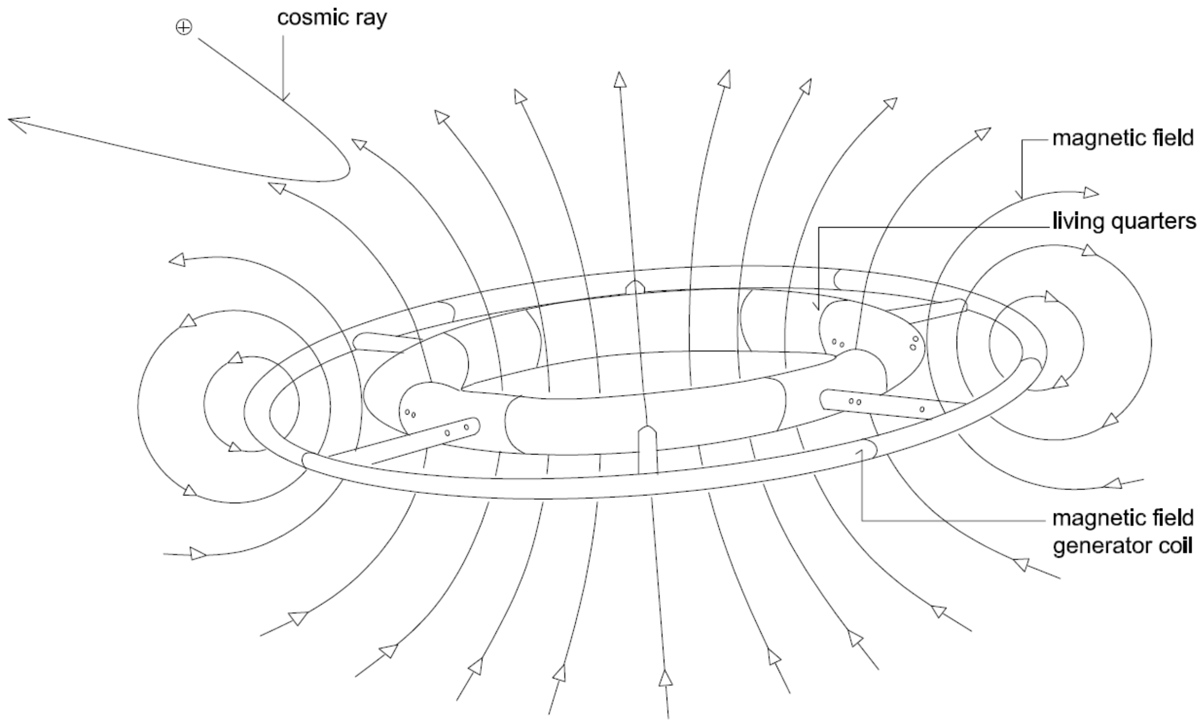

Figure 2. Artificial magnetic shield designed for the protection of a spacecraft against cosmic rays (from Ref. 7).

IV. The problem of micrometeorites

The second main problem we faced with is about the protection from the impact of micrometeorites, which could be extremely deleterious and lethal. A micrometeorite as large as a tomato seed may perforate a spacesuit and thus damage the transparent shell that encloses the lunar base. These small fragments travel at speeds of about 160.000 km/hr and, in case of lack of an atmosphere that slow them down as on the Earth, even smaller ones can generate craters on the lunar surface and destroy everything founded on their way.

For these reasons, we have thought to use the same structure that support electrical cables, which generates the artificial magnetic field, to support a shield made of a material resistant to the impact of these elements. The protected area will be only the portion above transparent domes of the moon base; the back face of this shield could be covered with a sort of "artificial terrestrial sky" made by adjustable mirrors that reflect and diffuse sunlight, illuminating the base ground.

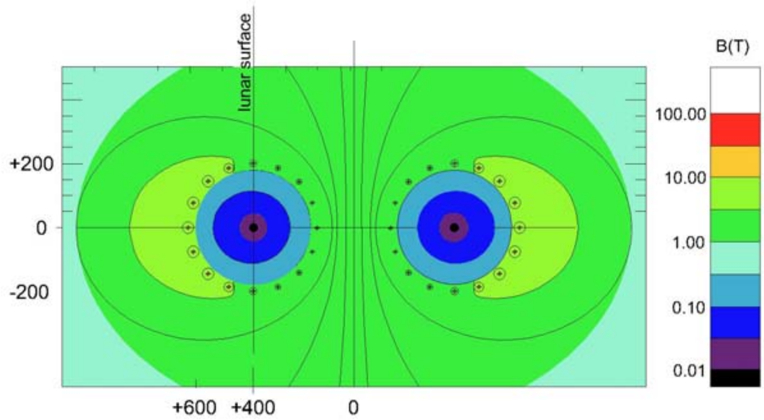

Figure 3. The electromagnetic field generated by a toroid.

V. Our proposal

We based our research on the simple statement that if, on one side, it is possible to protect the lunar base from cosmic radiation with an artificial magnetic field, on the other side this magnetic field must be sufficiently weak inside the base area to avoid damaging itself the inhabitants.

Our project move on from a serie of studies compiled starting from the Sheperd and Stormer's research, related to the magnetic field generated by conductors arranged circularly or with toroidal conformations, for which it is shown how within the circular section of the toroid the magnetic field is very low. On the outside of the conductors circle, instead, it is possible to obtain a sufficiently strong magnetic field, depending on the intensity of the current flowing through the cables (in the order of 1TW), which could protect from particles of cosmic radiations.

In particular, by adjusting the current intensity between the internal and external cables (for example by investing the external cables with a current intensity 5 times bigger than the internal ones) it is possible to generate a 10-15 T magnetic field, that studies believe could be enough to protect the human habitat.

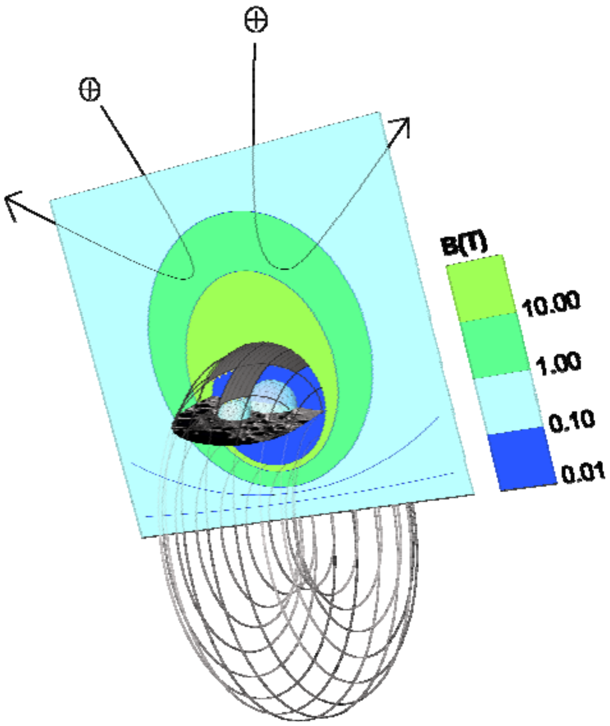

Figure 4. The magnetic-field free area inside the toroid circular section that allows human settlement.

Until now, these studies have been carried on for the protection of spacecraft crews from the long exposure to cosmic radiation (see Ref. 2). In our case, we applied the same concept to a hypothetical Moon or Mars base.

Our project involves the realization of a toroid made by16 conductor cables, with 200 m radius and 1200 m global diameter. The lunar base is located where the magnetic field reaches the lowest values, near the center of the

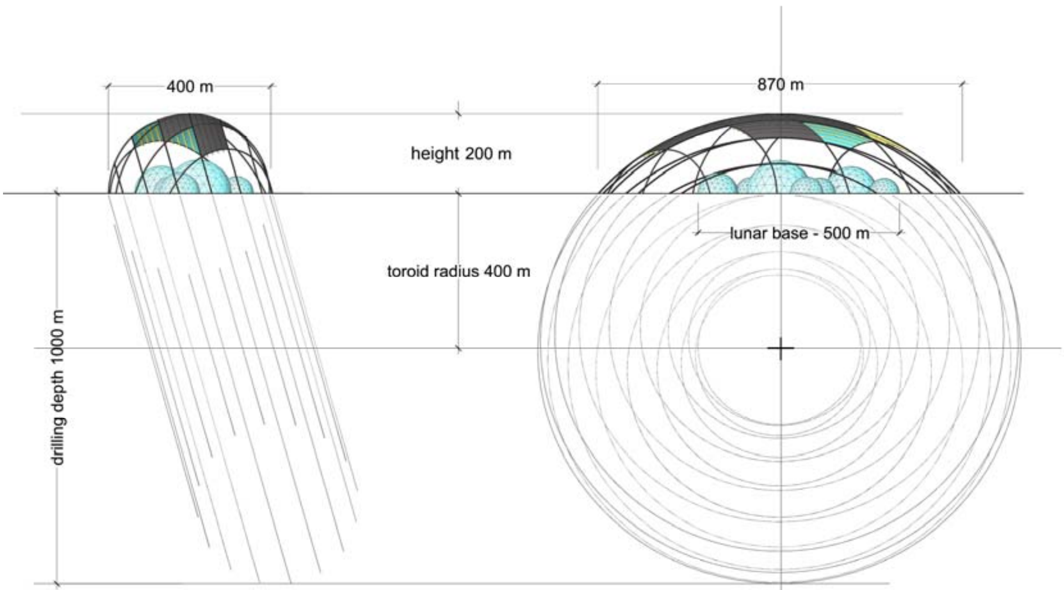

Figure 5. Frontal and lateral view of the lunar base proposed, with principal dimensions.

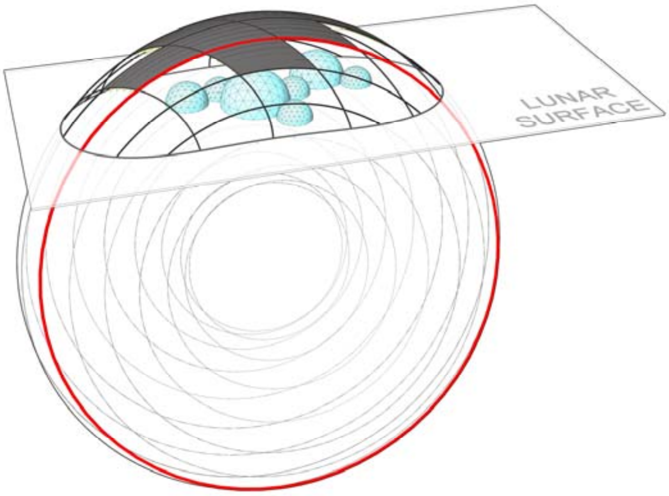

Figure 6. Three-dimensional representation of the lunar base with marked in red one of the 16 electric cables that flow above and below the lunar surface.

circular section of the toroid. Above the transparent domes of the base, the upper cables of the toroid are arranged at a maximum height of about 200 m, continuing their circular trajectory under the lunar surface for a maximum depth of about 1000 m.

The over-ground electrical cables cover an area of about 850 m x 400 m within the lunar base is protected by radiation; they are supported by a Vectran-type inflatable, lightweight and highly durable structure, intersected by a further orthogonal structural mesh that, in addition to aligning the cables, can support the superior shield for the protection against micrometeorites. Due to the transparency of the domes shell, it will be necessary to protect it from the micrometeorites impact: the protective shield will be placed at the level of over-ground electrified cables, at a sufficiently large distance from the summit of the domes (as said, about 200 m high while the domes height is about 50 m) so as not to obscure the view of lunar landscape and, partially, the celestial vault. The back face of this shield will be covered by adjustable mirrors that could reflect and diffuse sunlight that hits the moon surface in an almost radiant way, as the base is thought to be placed at the lunar South Pole.

Between one mirror and the other, shield can be painted of blue and white in order to recreate a kind of "artificial sky" or "artificial cloud", in order to psychologically comfort the inhabitants with a visual reference to the colors they are used to seeing on the Earth.

The size of the protected area therefore depends only on how large the conductor toroid is intended. It will only be a matter of cost, especially in reference to its underground part that need to be excavated along the path committed by the conductors: in this first version of the project, it will be necessary to dig 16 circular ducts for a depth of about 1 km under the lunar surface sufficiently large to flow inside the cables.

Depending on the size of the toroid, the inhabited area could be smaller or larger and accommodate a certain number of inhabitants: in this project, we have thought the human habits as a series of domes that are organically interconnected to each another in a single entity that constitutes an autonomous ecosystem.

The load-bearing structure of the domes, being mainly sustained by the internal pressure necessary for living space (approximately 1 atm), is made of tensile cables (about 10 cm in diameter spaced at a distance of about 1 m) that support a double-glazed cushions made of transparent high-strength material (ETFE type).

This double-glazing is designed on one side to maintain a high level of security in case of weakening of the outer layer (which is however protected against the possible impact of micrometeorites from the top shield) and on the other side to provide

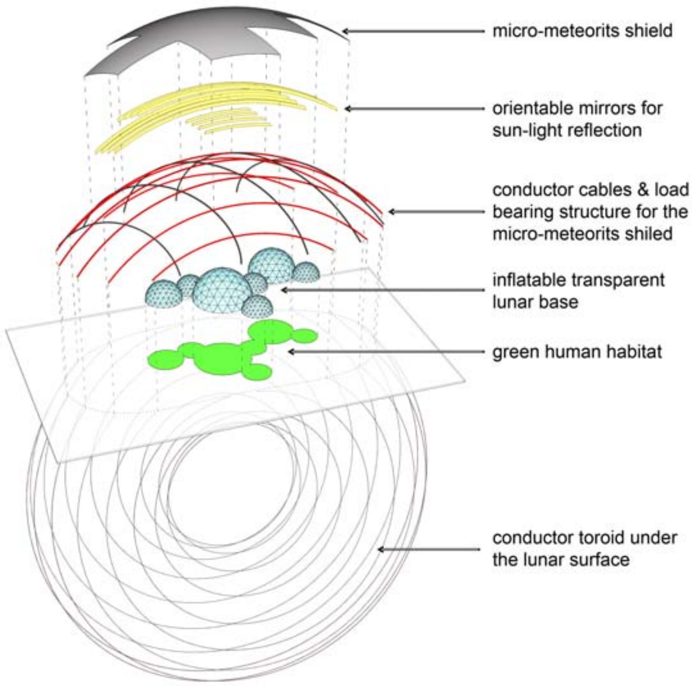

Figure 7. Exploded view of the components that constitute the lunar base.

thermal insulation that dampen the great temperature range typical of the lunar surface.

Within the domes, it is possible to recreate a habitat that is as similar as possible to the Earth, in order to mitigate the psychological risks connected to the distance from our mother planet; an extremely clean environment that obviously has no harmful emissions in which to experience innovative technologies that we could apply even on our planet.

We have made several models with different planimetric conformations of the lunar city, more or less adapted to the contour of the lunar surface and more or less integrated with technological equipment and devices such as photovoltaic panels for the power supply needed by the magnetic field, or as appendices for the positioning of particular observers or laboratories. Anyway, the concept that keep ahead the design of our moon-base, however is it made, is to protect it from both the main risks to which it is exposed, which are micrometeorites impact and cosmic rays, by the combined action of a physic and a magnetic shield.

VI. Conclusion

We hope that this preliminary research may be encouraged a future develop of our concept and a deeper study on themes and topics covered in this contribution, that, why not, in the next future will bring human to realize the dream of living on the moon without being enclosed under heavy metal cages or dark rock caverns.

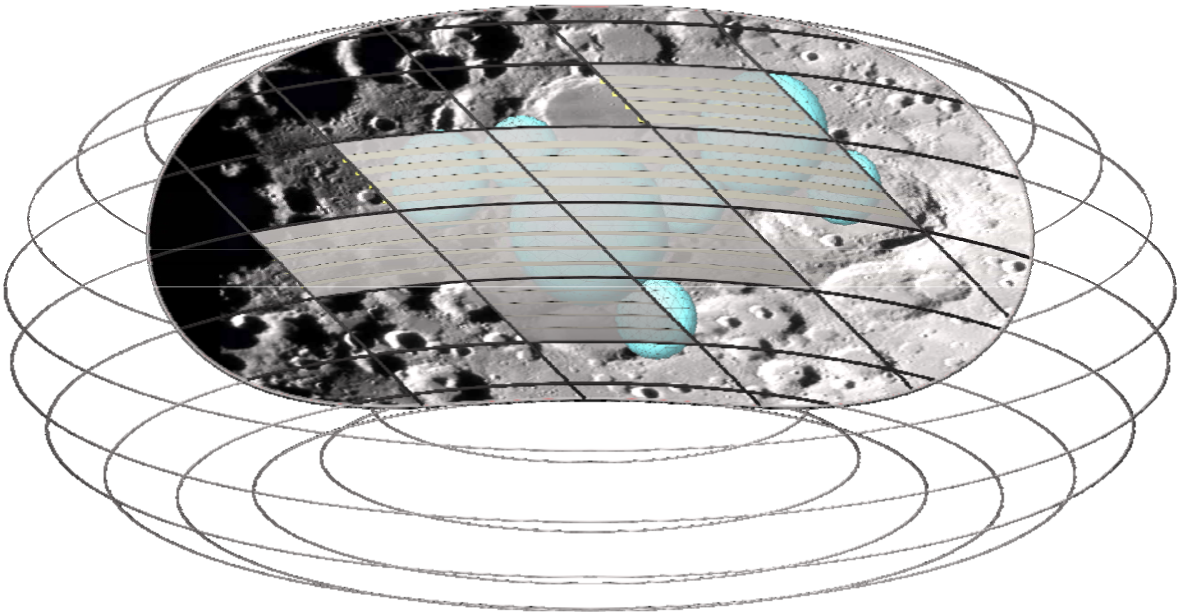

Figure 8. Zenithal view of the moon-base concept.

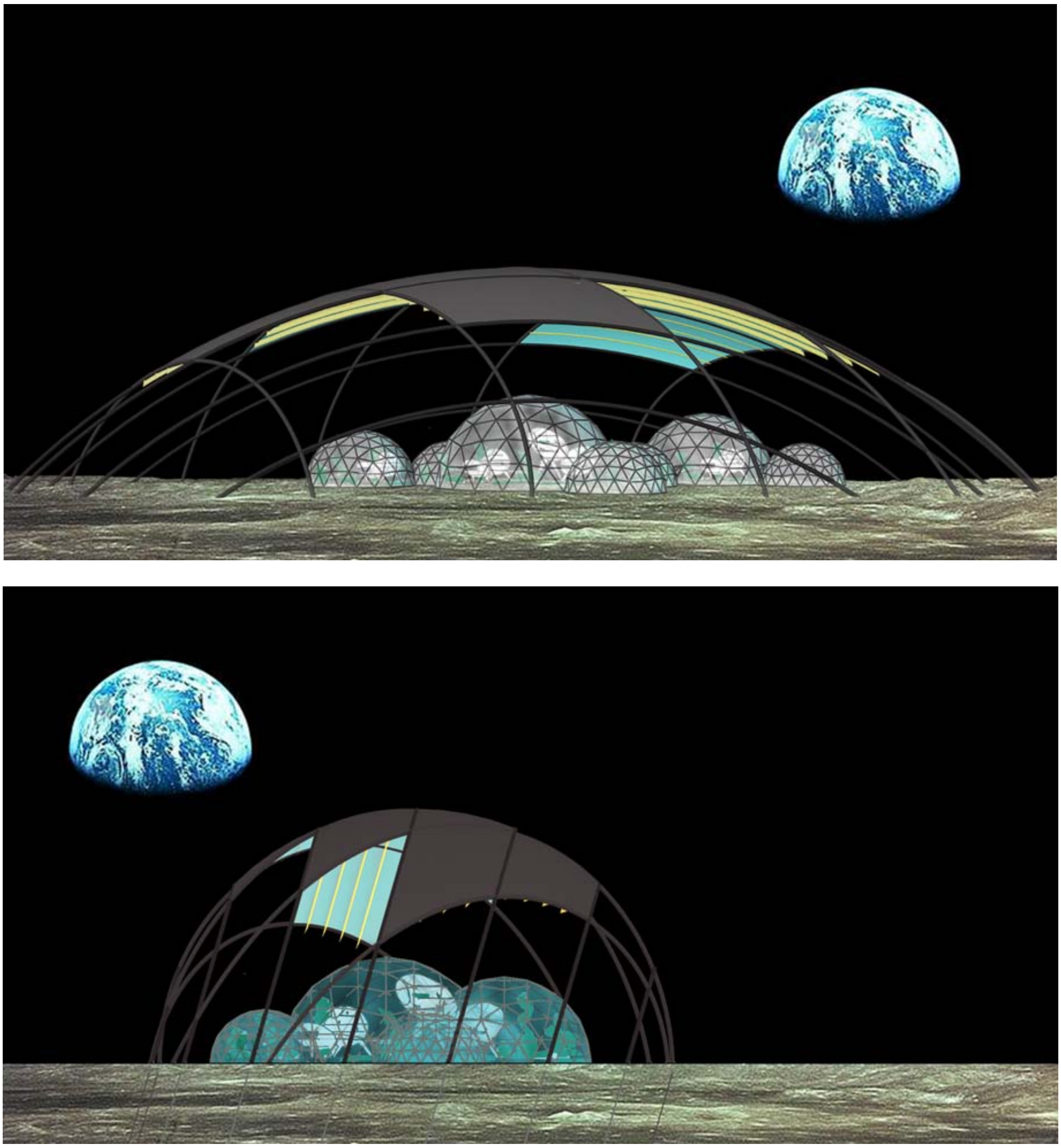

Figure 9. Frontal and lateral view of the moon-base concept.

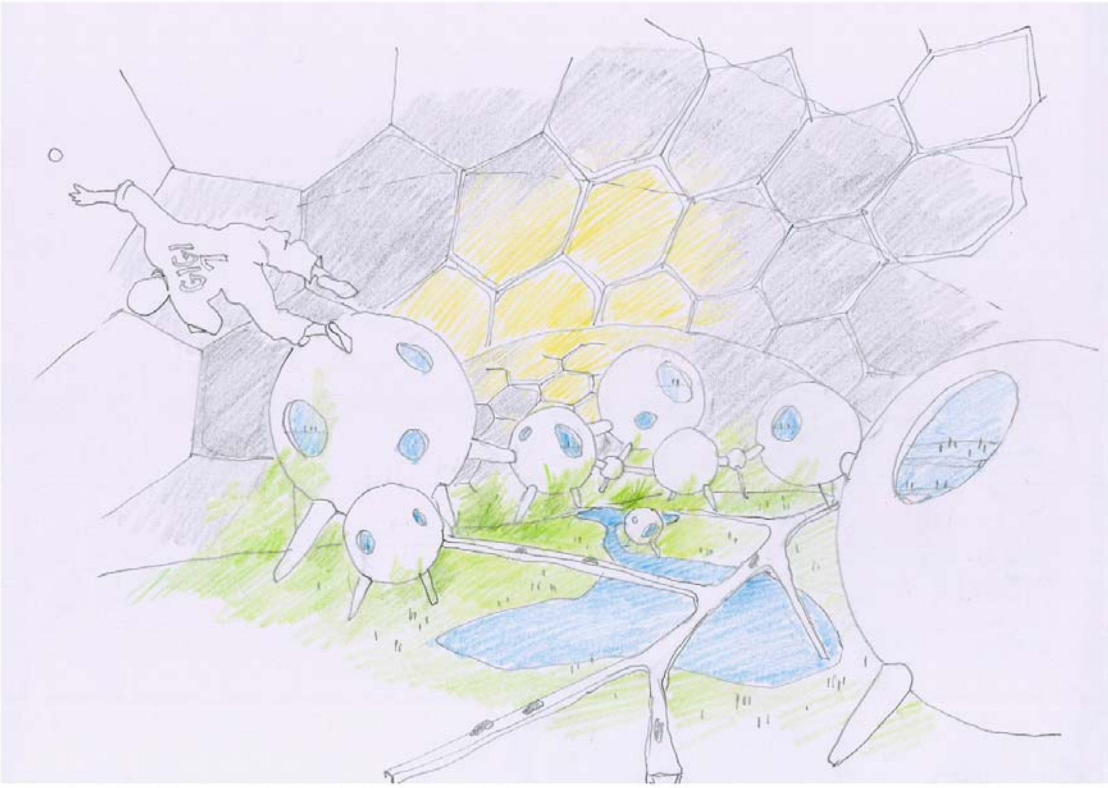

Figure 10. Artistic representation of the environment within the lunar base.

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