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# Researches on a Martian Modular Base Shielded by an Artificial Magnetic Field

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**Abstract:** This proposal for the future colonization of Mars starts from the purpose of creating an expandable and modular community made of elements as transparent as possible with large windows that allow the view of Martian landscape as to mitigate psychologically effects derived from long stay away from planet Earth. To realize this aim, it will be necessary to protect the settlement from the dangerous cosmic rays that the Martian atmosphere could not sufficiently shield, at least in relation to the long period of stay expected for the future settlers. It will be demonstrated that it is possible to reach this goal by positioning the inhabited elements of the future base below a huge toroid made of electric cables driven by high voltage current that generates externally a magnetic field strong enough to shield the cosmic rays but, at the same time, almost null inside of it. To confirm this hypothesis, it has been realized a scale model of the Martian base, made by some electric cables arranged around a toroidal frame and run by low voltage current. The tests demonstrate that inside the toroid section the magnetic field is actually almost null, while outside it reaches values directly proportional to the current intensity that has been used to power the system.

**Keywords:** Mars Colonization, Human Settlements, Magnetic Field, Cosmic Rays, Magnetic Shield

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## 1. 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. But it's known that coming out of Earth and moving away

from it for long periods involves exposure to great risks and a series of problems that for permanent colonies become infinitely bigger than those who have been solved until today for the small space travel that man has done.

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. This proposal tries 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. [1]

Therefore, in this research, it's been proposed a Martian base (similarly to the one presented at SPACE AIAA 2017

for a lunar base [2]) as open as possible to the surrounding landscape and to the view of the Sky vault, as to create comfort for the inhabitants who might feel closer to the Earth.

This will be possible by rejecting dangerous cosmic rays from the inhabited colony through the creation of an artificial magnetic field that will deflect the positively charged particles of cosmic rays, just as it happens on Earth. The purpose of the research is not focused on how to organize or realize the living spaces of the future settlement, but on the design of the protection system below which the future homes will be installed. In this first phase, it is demonstrated through both numerical calculations and a scale model that the toroidal arrangement of the electrical cables seems to be the best way to create an artificial magnetic field outside the volume defined by the cables with, at the same time, a null intensity inside of it.

## 2. The Problem of Cosmic Radiations

The average radiation dose to which a human is exposed in a year living on Earth is about 3.6 milliSieverts (mSv), thanks' to

the presence of a dense atmosphere that shields the cosmic rays (see Figure 1). People employed in particular radioactive industrial activities may be exposed to a maximum of 50mSv per year, while for astronauts is accepted 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 tolerable. [13]

For a Martian settler the acceptable limit would depend on how long he stops in the 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 would be required to protect the Martian base.

Generally, in most of the projects developed over the years, it is proposed to protect the future base with a considerable layer of soil 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, 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.

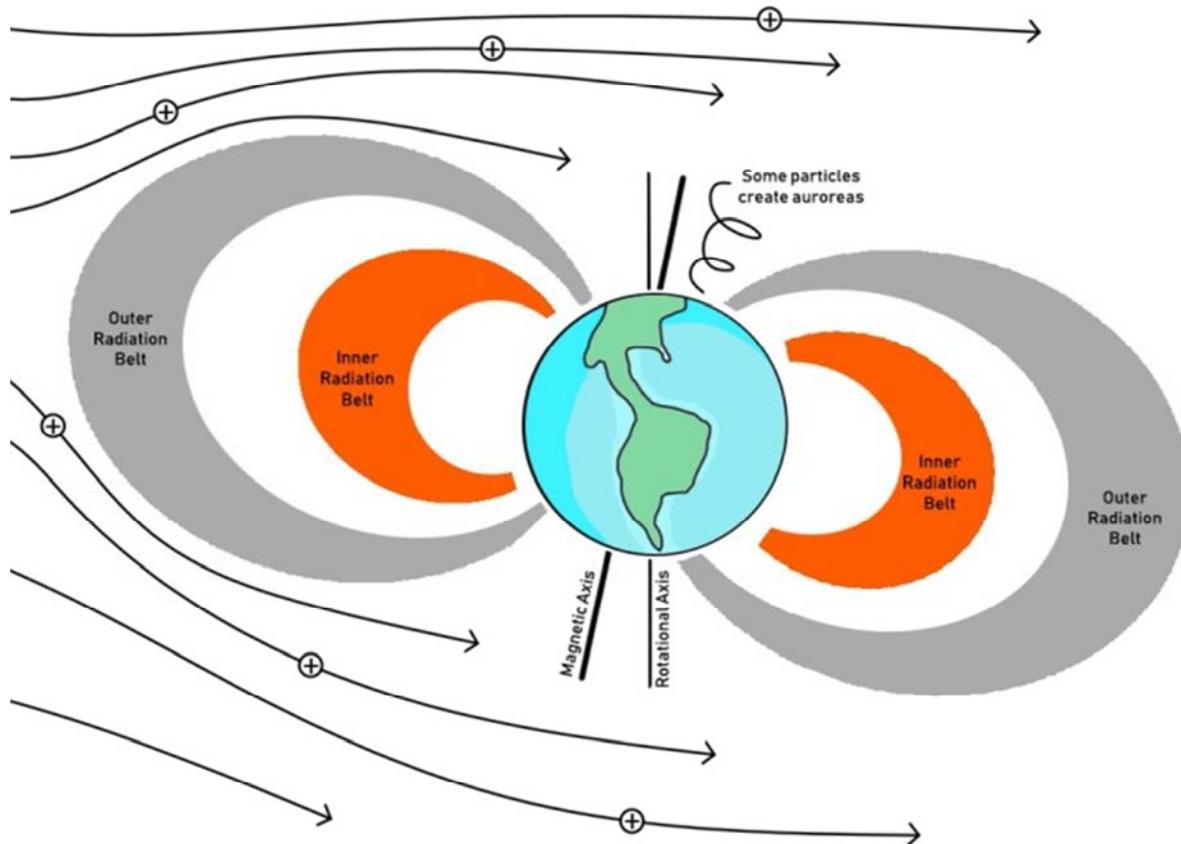


Figure 1. The terrestrial magnetic field protect the Earth from solar wind.

Alternatively, the base could be built within so-called "lava tubes" that are natural cavities or deep tunnels in the Martian 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  $-20^{\circ}\text{C}$  instead of varying outside from  $-173^{\circ}\text{C}$  up to  $+100^{\circ}\text{C}$ . "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 external landscapes and celestial vault, buried in the dark under a huge protective layer.

### 3. 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 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 cable proper protection and insulation to maintain such a low temperature.

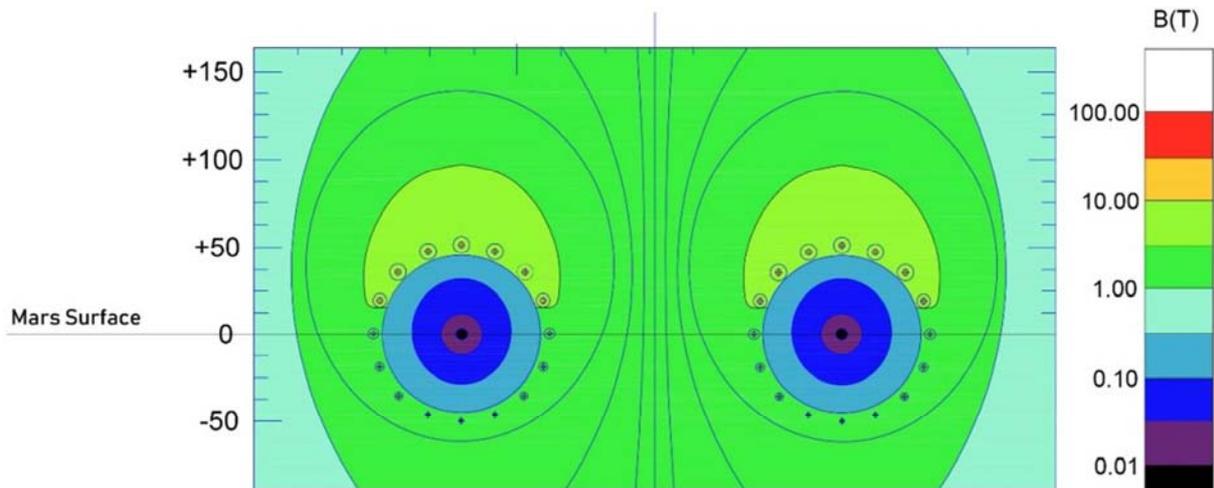


Figure 2. The electromagnetic field generated by a toroid of electric cables.

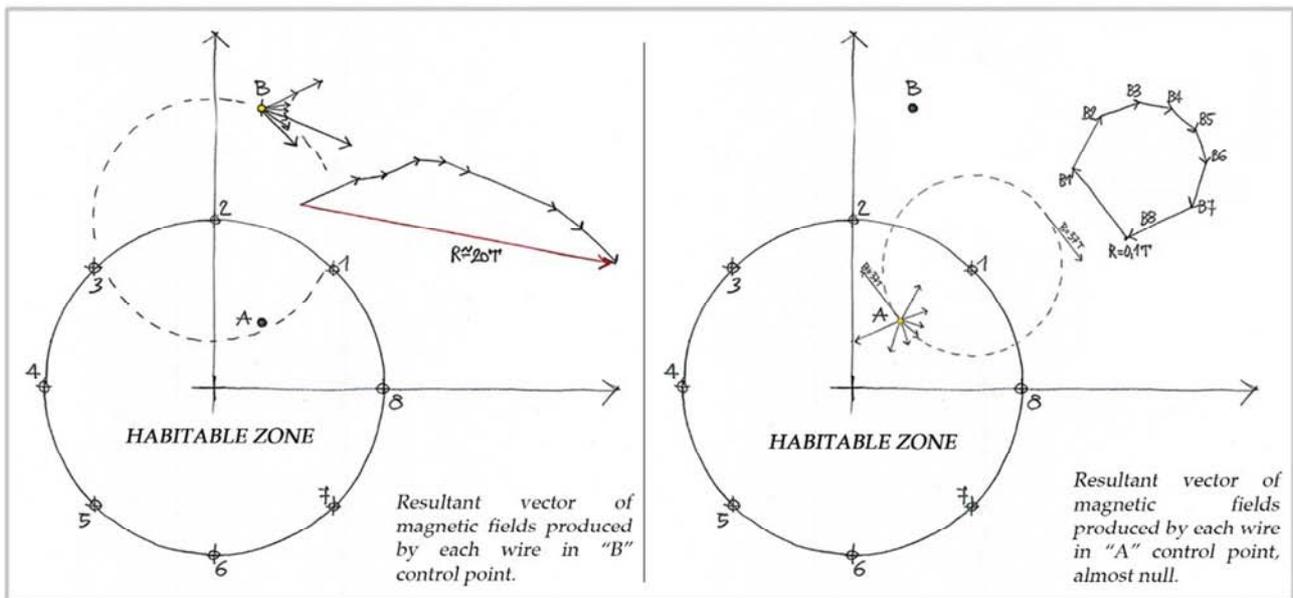


Figure 3. Simple example of calculation of the electromagnetic field generated by a loop of cables.

Figures 2 and 3 shows variation of intensity of a magnetic field produced by a preset number of electrical wires (in this case, eight), arranged circularly in a given point (named “control point”), placed either outside or inside the circumference.

The intensity of the magnetic field generated by each wire in the control point is represented by a vector, directed tangentially to the circle that pass through the control point and that is centered in the wire.

The vector resulting from the sum of the individual contributions represents the overall intensity of the magnetic field in the control point: when this is placed outside the circle of wires, single contributions add intensity and the resultant vector increase the nearer it is to the electric wires. Otherwise, when the control point is

taken inside the circle, the magnetic fields produced by single wires have opposite directions and they delete each other, so that the resultant vector is almost null. The realization of a scale model of the electric wires toroid has confirmed the rightness of this assertion, as it is shown by both the measurements made with a professional magnetic detector and simply by using a compass (as documented in Figure 4).

Taking advantage of this, inside a Martian settlement surrounded by high-voltage electrical wires, the environment could be habitable for humans without any risk of being damaged by magnetic fields and, at the same time, protected from the irradiation of solar wind and its cosmic rays (see Figure 5).

### 4. Details of the Paper Proposal

This project move on from a series of studies compiled starting from the Sheperd and Stormer's research [9], related to the magnetic fields 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 current flowing through the cables (in the order of 1TW), which could protects from particles of cosmic radiations.



Figure 4. Some views of the scale model realized to demonstrate the absence of magnetic field inside the toroidal arranged cable frame.

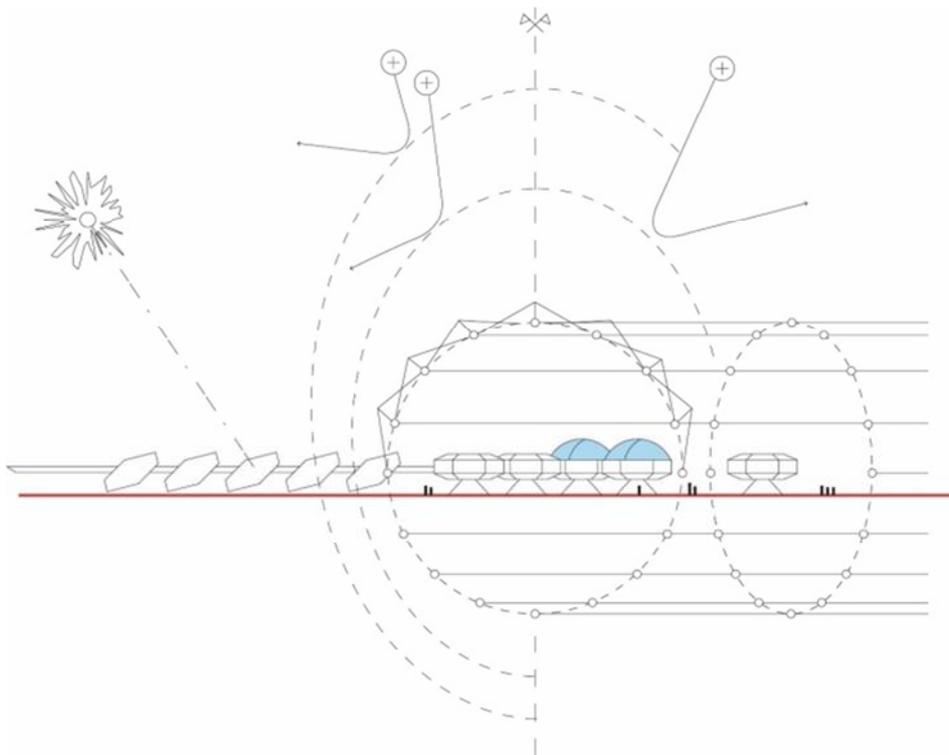


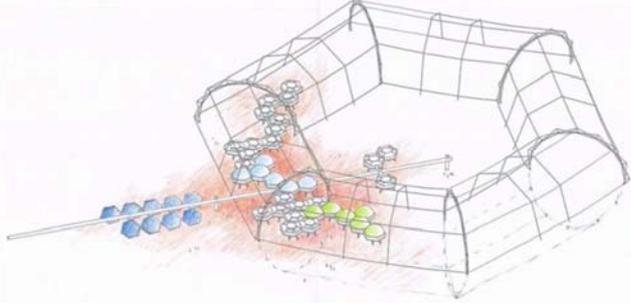
Figure 5. Vertical section of the settlement with detail of circular arranged electrical cables that generate magnetic field.

Until now, these studies have been carried on especially for the protection of future spacecraft crews, which are exposed during long-time space travel to high quantities of cosmic radiations. Moving ahead from this concept, the same theory of artificial magnetic field used as a shield has been applied to a lunar base, protected from solar wind by a huge toroidal-arranged cable frame, placed vertically and partially

emerging from ground (this study was presented in 2017 at the AIAA SPACE FORUM of Orlando). Now, the same concept has been extended and developed for a Mars base and to the spaceship that allows reaching the red planet. In fact, unlike that for the moon, the journey to Mars has a particularly high duration considering the current propulsion technologies (approximately 8/9 months) and it is necessary

to solve the issue of protection from cosmic rays also during the voyage. In this way, it will be possible to plan the trip also not in correspondence with the conjunctions of proximity between the two planets.

For these reasons, it has been necessary to design an innovative spaceship made of modular habitable units that, once reached the Martian orbit, decomposes itself assembling a modular settlement on Mars surface (see Figure 6).

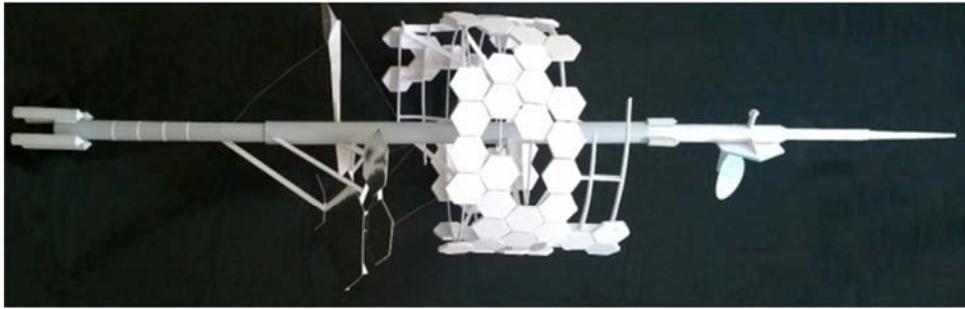


**Figure 6.** Perspective sketch view of the settlement, once assembled on Mars.

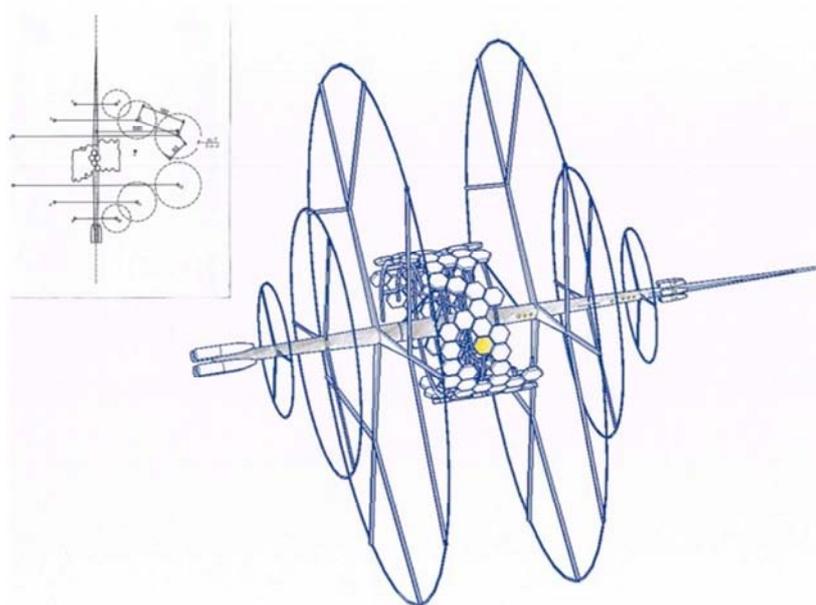
In particular, two types of space ships have been developed, both composed by modules that will constitute the

Martian village: in the first version (Figures 7 and 8), the modules are arranged forming a cylinder around a central axis, which house propulsion, navigation and communication systems.

A further development is a sphere-shaped vessel (see Figure 9) in which the modules destined for the descent on the Red Planet are hung during the going voyage at the external structure, while for the return (presumably towards a cis-lunar assembling orbit) the vessel crew will stay in the remaining modules that will rotate around a different rotary axis. At the boundary of the "traveling sphere" there will be the propulsion systems necessary for both the voyage and the contemporary rotation of the space vessel, in order to generate artificial gravity during the roundtrip. The reason why this second model of spacecraft has been developed was to better integrate the load-bearing elements of the ship with the structure of the modules. The bearing structure of the sphere, which constitutes the body of the vessel, is formed by a hexagonal and pentagonal diagrid and therefore it's easier to connect and aggregate the modules, which has similar shapes.



**Figure 7.** Scale model of the settlement assembled in the cylindrical spaceship around the orbit of Mars.



**Figure 8.** Sketch of the early version of the spaceship (more traditional) with the electric cables around the ship to protect itself from the cosmic rays during the journey.

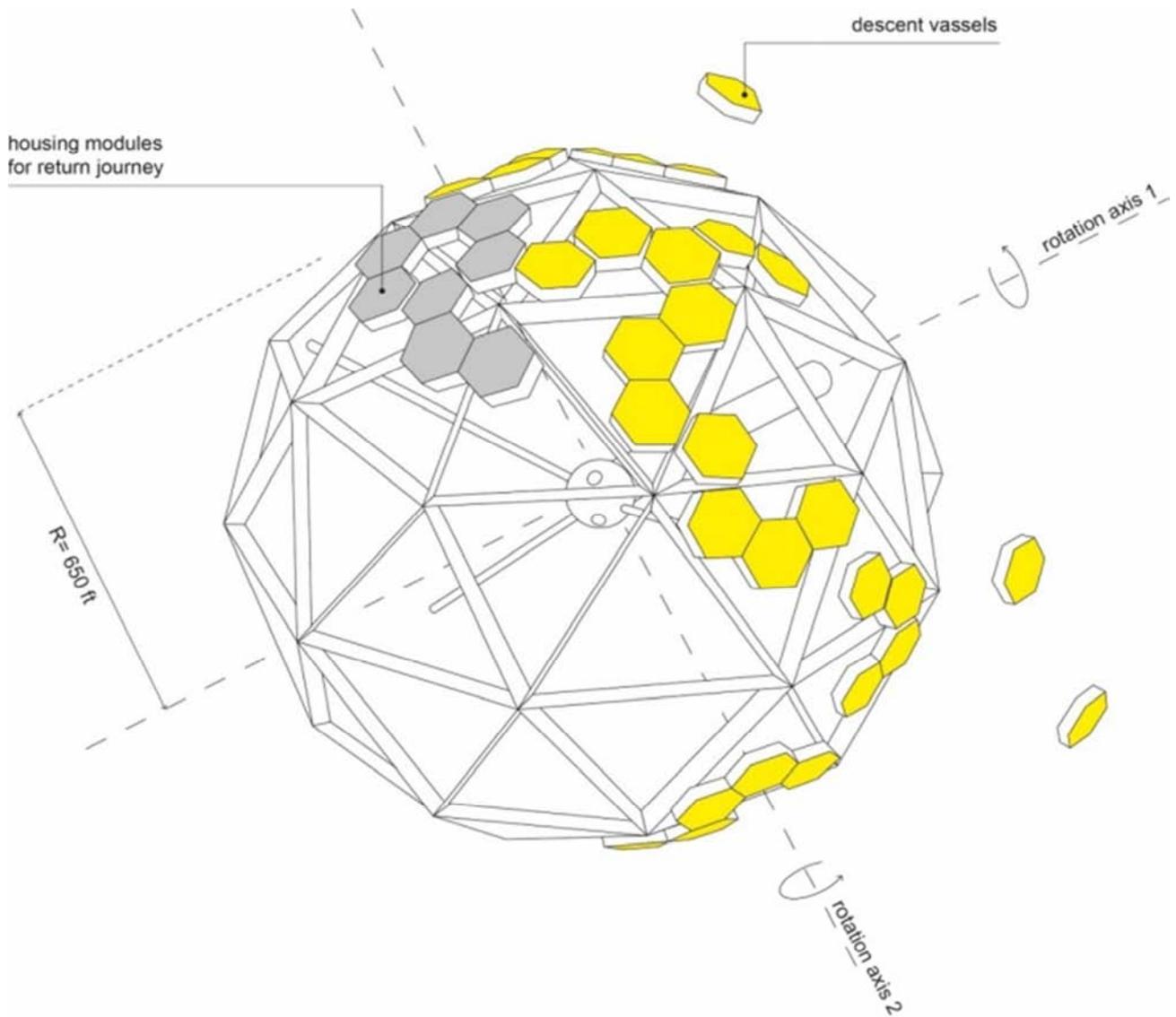


Figure 9. Perspective view of the sphere-shaped vessel.

Both type of ships are protected during the trip from dangerous cosmic rays with an artificial magnetic shield, generated by a series of electric cables that envelop the ship's structure, appropriately detached from it in order to allow the safe detachment of the modules.

Once in Mars orbit, the ship-sphere will stop its rotation and will begin to release each modules one by one (as shown in Figure 10). These will independently descend on the planet and gradually begin to place themselves under the dome constituted by the network of protection cables, already prepared by previous missions.

At the same time, from the central core of the vessels, some spacecraft will depart with on board the future settlers that will land on the planet in a more conventional way, according for example to the technology that Elon Musk developed with BFR transport system, expressly designed for Mars.

To protect the future settlement from cosmic rays once they are landed on Mars, it will be used the generation of an artificial magnetic field through a series of high voltage

electric cables arranged in a toroidal geometry around the inhabited environment. This cables are able to generate an external magnetic field of 4/5 Tesla of intensity, enough to reject cosmic rays, and, at the same time, an almost null magnetic field inside the settlements, as to avoid any damage for the inhabitants.

Each single element that will be part of the modular settlement on Mars, will be aggregated to the others creating a cylinder (or a sphere as in the second proposal) of about 300 m radius, which will be the core of the spaceship for the voyage from Earth or, more probably, from a cis-lunar orbit where the assembly of the spacecraft takes place.

During the journey, the spaceship will rotate at 1.5 round per minute around its central axis in order to generate a force of gravity of about 0.8g, as to avoid physical contraindications for the crew during the travel.

As already said, once the ship will reach the orbit of Mars, each element will detach from its position and descend on the red planet through a system of parachutes and thrusters, which will slow down the descent by friction with the slight

atmosphere and allow a precise placement on the planet ground. Each module is equipped with four motorized legs that will allow fine movements required to realize a precise connection with the other units.

The basic module is a hexagon inscribed in a circumference of about 20 m diameter, and it is high enough to create inside it habitable spaces. The weight on the Earth of each module would be about 40-50 tons, including the fuel needed for the descent. Modules are differentiated according to the function that they will accomplish in the Martian settlement, so they are originally designed and produced with different internal paths and distribution of rooms (Figure 11). Each configuration must also work when they are assembled in the spaceship, so that they can be inhabited, at least partially, also during the journey.

Each of the modules will be lifted from the ground of about 5 m to allow the Martian wind to run off during sandstorms, as to prevent any accumulation of sand on the modules that would obstruct the outside view (as represented in Figure 12).

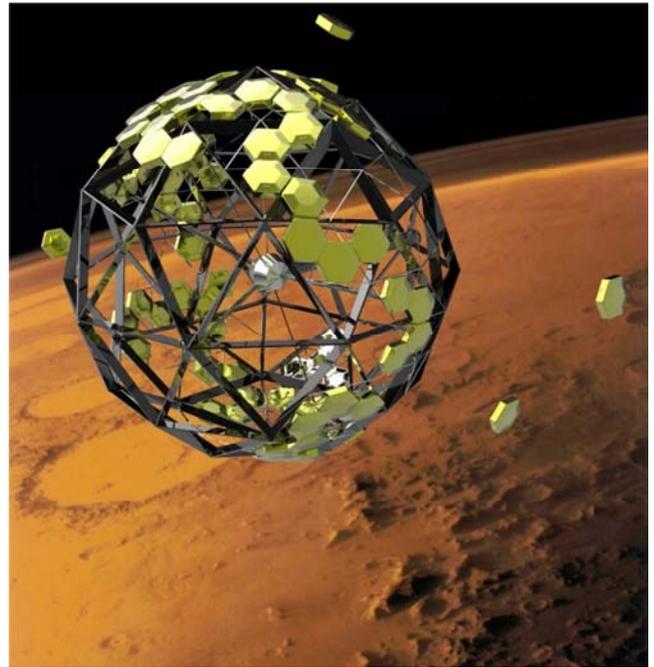


Figure 10. View of the sphere spacecraft in Martian orbit.

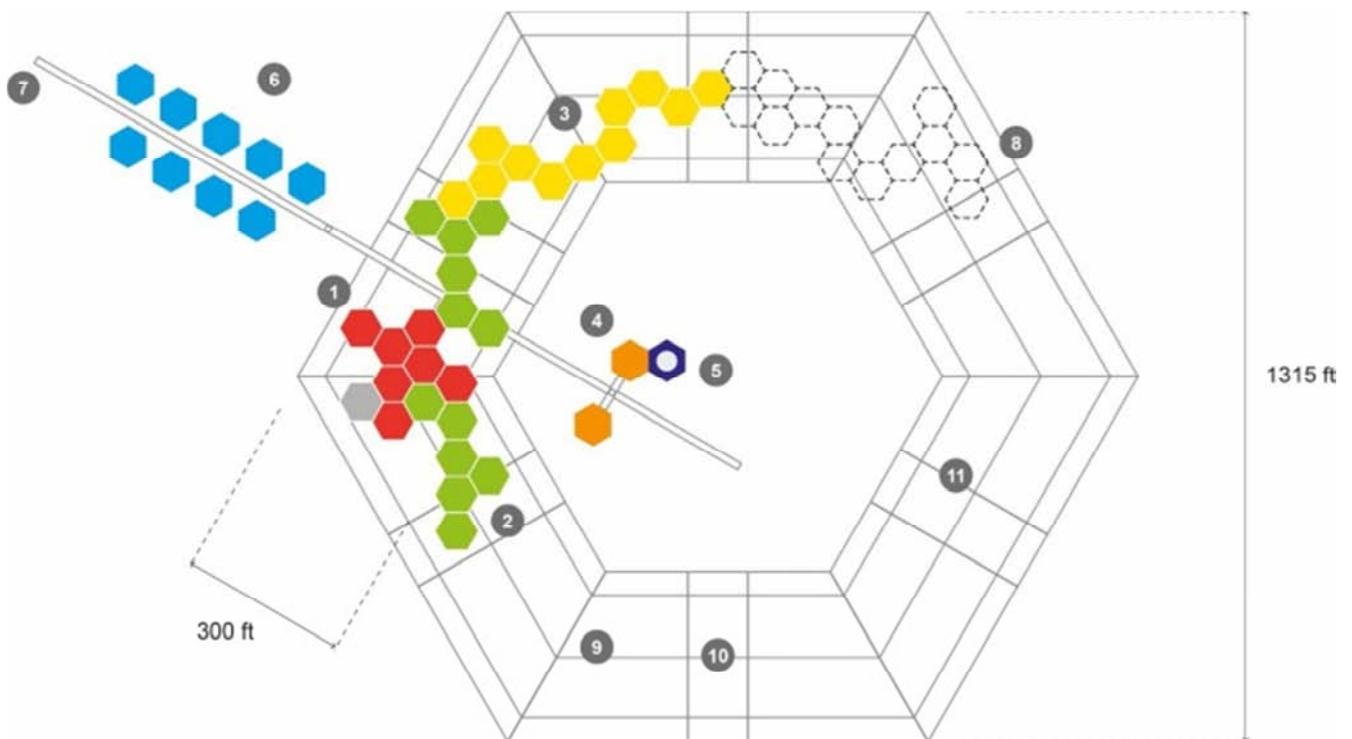


Figure 11. Master plan of the settlement developed on Martian surface. 1) common areas for work and meeting; 2) greenhouses and relax areas; 3) private and collective housing units; 4) hangar modules and warehouses for explorations and external works; 5) observatory; 6) photovoltaic panels; 7) technological distribution axis; 8) future further expansion of the base; 9) load bearing structures for electric cables; 10) electric cables that generates the artificial magnetic field; 11) bracing cables.

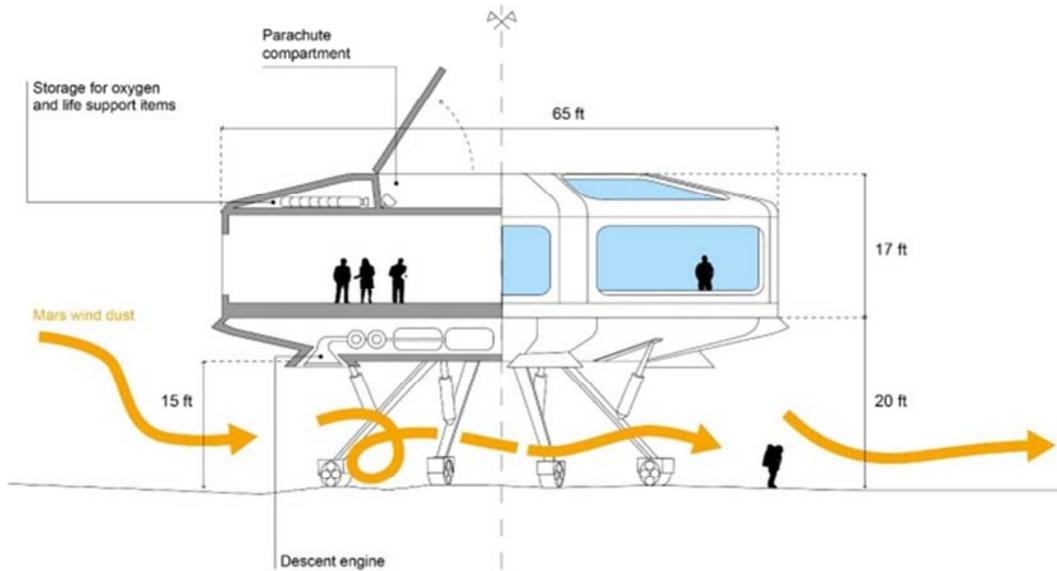


Figure 12. Technical section of one housing module.

Once the modules have been positioned and hooked together, the settlement will be completed by installing the electrical cables above the ground (Figure 13), as to complete the toroid together with the underground portion of cables that had been previously positioned by a group of first settlers, who had previously come down on the planet to prepare the site. By flowing electricity in the circuit, the magnetic shield against cosmic rays will be finally generated.

A settlement protected from cosmic radiations will allow the realization of large glazed spaces, both on sidewalls and on roofs (for example, in case of greenhouses with intensive crops – Figure 14). This will ensure a much more habitable environment for the inhabitants, who will appreciate the Martian landscape and the sunlight from the inside of their settlements.

The base will be completed by the construction of a "technological axis", a walkable tunnel lifted from the ground where to install the batteries of photovoltaic panels and small nuclear reactors for the production of the huge quantity of electricity needed to power the base and, at the same time, to generate the artificial magnetic field. Garages and warehouses for the exploration vehicles may be further elements of the technological axis, together with astronomical observatory.

Once this first phase of permanent colonization of the Red planet will be completed, the spacecraft will undertake the return journey. In the sphere version, some of the modules will be reserved for the return journey, which will be executed with a second rotation axis, as to continue to guarantee an artificial gravity to the astronauts.

The journey will end in a cis-lunar orbit, where it will be possible to reassemble the ship with new modules and eventually return once again to the Mars for a further upgrade of the base.

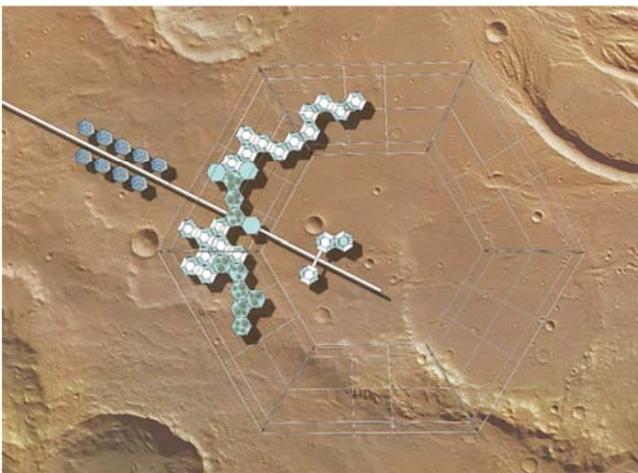


Figure 13. Masterplan of the settlement developed on Martian surface.

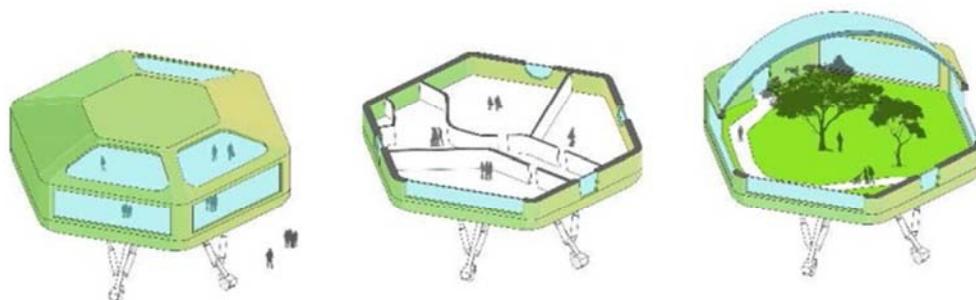


Figure 14. Perspective and section views of some modules.

## 5. Conclusions

This paper describes how artificial magnetic fields can be used as a protection for human settlements on planets with a weak atmosphere such as Mars, shielding from the dangerous cosmic rays that run across the outer Space. The research deal on the finding of the optimized arrangement for the electrical cables as to generate a magnetic field that has enough intensity to reject cosmic rays but, at the same time, does not become harmful for human near it. The toroidal configuration proved to be the most efficient one, in order to nullify the magnetic field intensity inside of its volume and together maximize it at the boundary. The realization of a scale model of the electric wires toroid has confirmed the rightness of this assumption: the complete absence of artificial magnetic field inside the volume described by the cables, which is confirmed by both the measurements made with a professional magnetic detector and simply by using a compass (as shown in Figure 4).

The aims and future developments of the research are to understand the exact value of current intensity necessary to deviate the cosmic rays and if it will be necessary to adopt superconductor materials to guarantee enough power to the system.

This preliminary research may be encourage a future develop of these theories 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 Mars for long period without being enclosed under heavy metal cages or dark rock caverns.

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