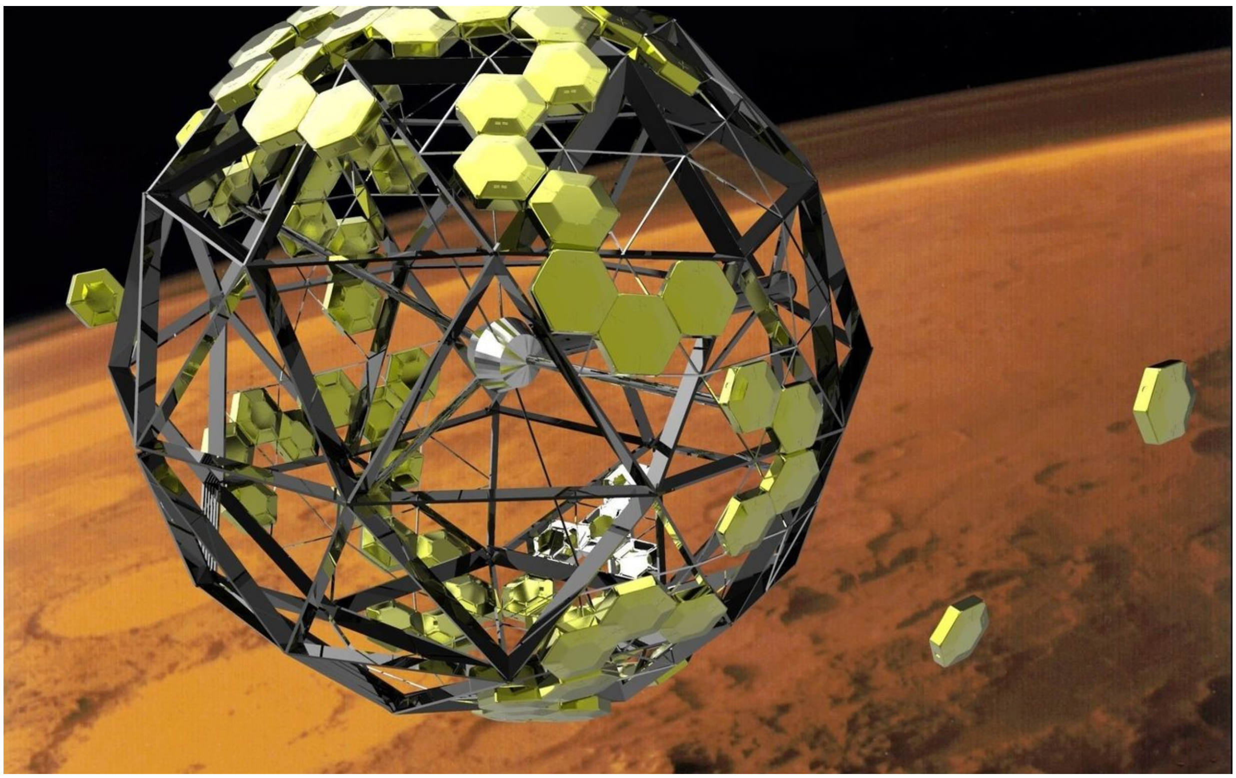
Plans for a modular Martian base that would provide its own radiation shielding

October 17 2018, by Matt Williams



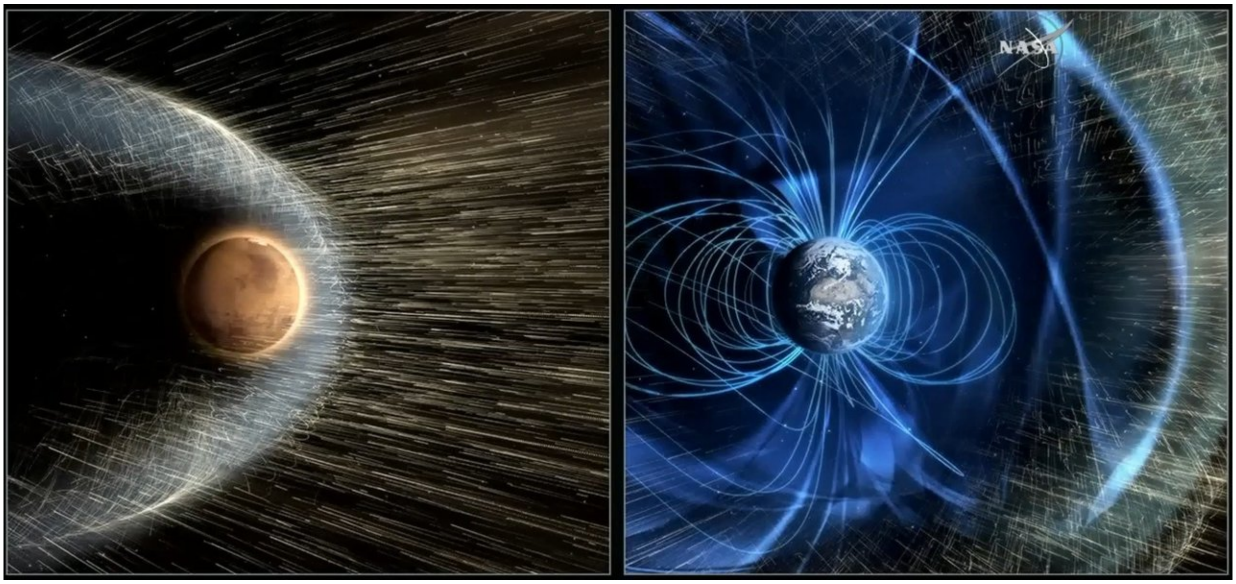
Credit: Marco Peroni Ingegneria

The idea of exploring and colonizing Mars has never been more alive than it is today. Within the next two decades, there are multiple plans to send crewed missions to the Red Planet, and even some highly ambitious plans to begin building a permanent settlement there. Despite the enthusiasm, there are many significant challenges that need to be addressed before any such endeavors can be attempted.

These challenges – which include the effects of low gravity on the human body, radiation, and the psychological toll of being away from Earth – become all the more pronounced when dealing with permanent bases. To address this, civil engineer Marco Peroni offers a proposal for a modular Martian base (and a spacecraft to deliver it) that would allow for the colonization of Mars while protecting its inhabitants with artificial radiation shielding.

Peroni presented this proposal at the 2018 American Institute of Aeronautics and Astronautics (AIAA) SPACE and Astronautics Forum and Exposition, which took place from to September 17th to 19th in Orlando, Florida. The presentation was one of several that took place on Wednesday, Sept. 19th, the theme of which "Mars Mission Architectures."

To put it simply, the idea of colonizing Mars (or anywhere in the solar system) presents many challenges – both physical and psychological. In the case of the Red Planet, these include its thin and unbreathable atmosphere, its very cold environment, and the fact that it has no magnetic field. It is this last item which is especially challenging, since any future colonists will need to be shielded from a considerable amount of radiation.



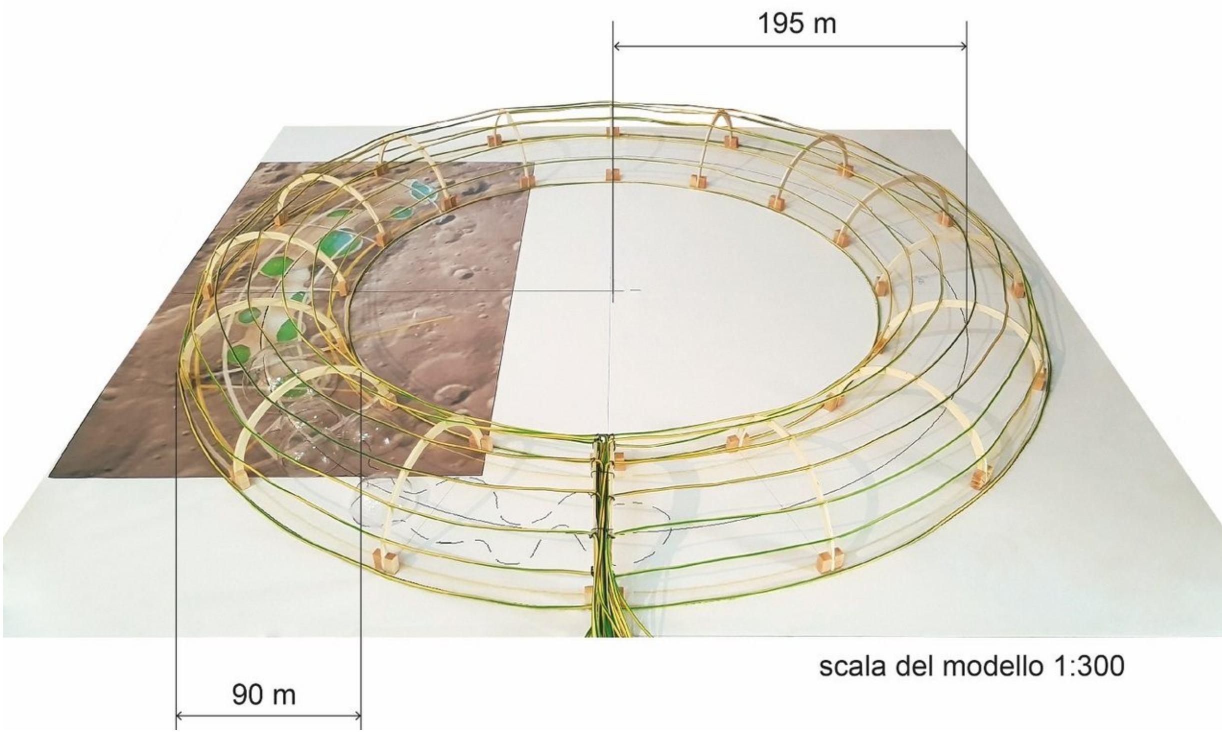
At one time, Mars had a magnetic field similar to Earth, which prevented its atmosphere from being stripped away. Credit: NASA

In short, the average amount of radiation that a human is exposed to on Earth works out to about 3.6 milliSieverts (mSv) a year, which is thanks to Earth dense atmosphere and protective magnetic field. Naturally, this means that astronauts and people venturing beyond Earth are exposed to drastically higher amounts of solar and cosmic radiation.

To ensure astronaut health and safety, NASA has established an upper limit of 500 mSV per year or 2000 to 4000 mSV (depending on age and gender) over the course of an astronaut's life. However, Peroni estimates that depending on how long they spend indoors, the average amount of radiation a Martian settler would be exposed to would be about 740 mSv per year. As Peroni explained to Universe Today via email:

"The amount of material for an effective shielding may then be well beyond what is practicable for most aerospace applications. The aluminum walls of the ISS, for example, are about 7 mm thick and are effective in LEO, but it is unlikely that such shields would be enough in interplanetary space, where they might even increase the dose absorbed unless substantially thickened."

To address this threat, previous proposals have recommended building bases with thick layers of Martian soil – in some cases, relying on sintering and 3-D printing to fashion a hard ceramic outer wall – and emergency shelters in the event of solar storms. Other proposals have suggested building bases in stable lava tubes to provide natural shielding. But as Peroni indicated, these present their own share of hazards.



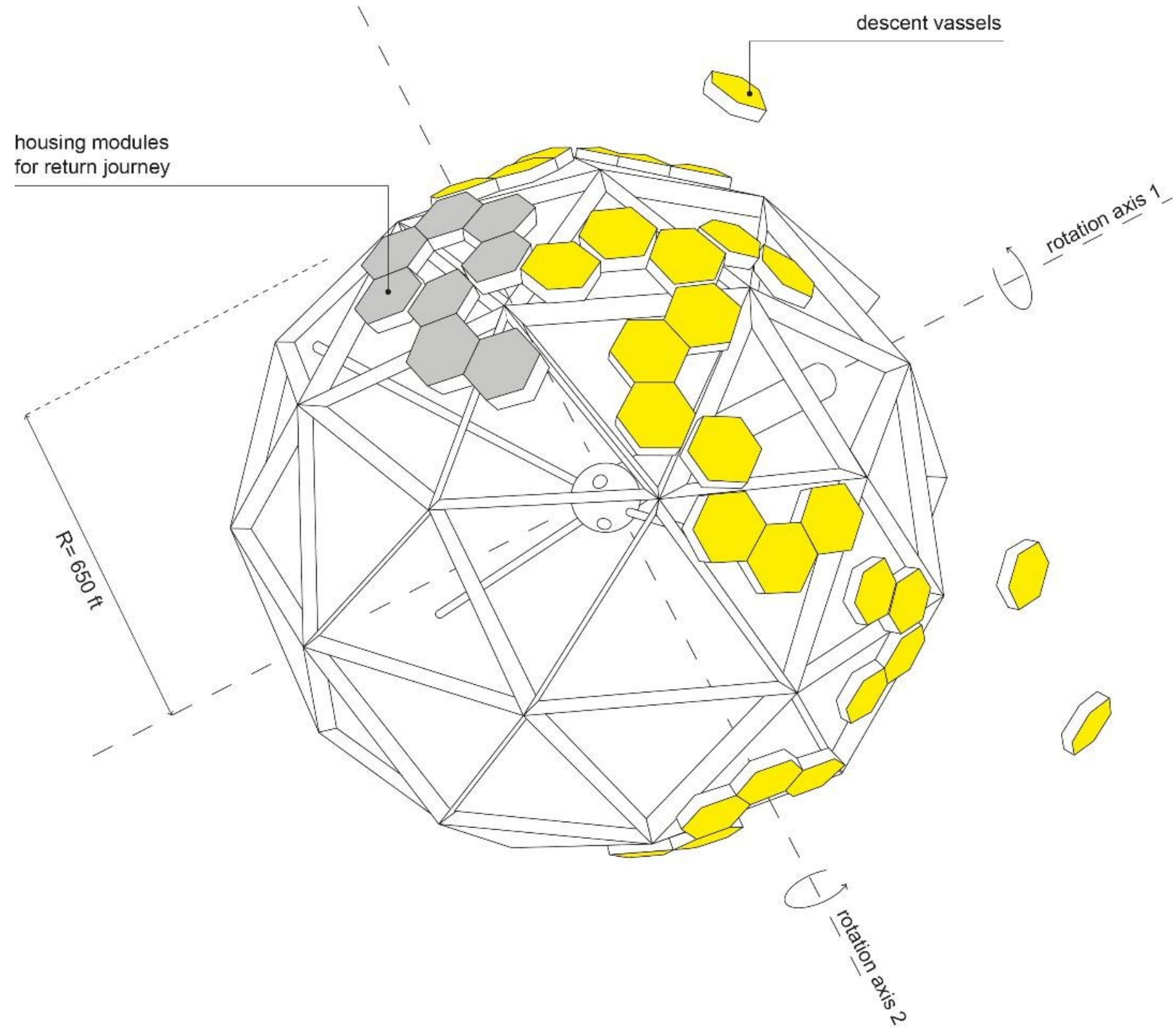
Artist’s impression of the apparatus that would provide artificial magnetic shielding. Credit: Marco Peroni Ingegneria

These include the amount of material needed to create effective shield walls, and the threat of claustrophobia. As he explained:

"A NASA study found that a large space station or habitat required a shielding of 4 t/m2 of Martian regolith (considering that its density is between 1,000 kg/m3 at the surface to 2,000 kg/m3 at a depth of a few cm, this corresponds to a thickness of 2 m, or less if the material is compacted [by being] sintered by lasers), to achieve an effective dose rate of 2.5 mSv/y…

"An underground shelter can be used also as sleeping quarters and for all those activities in which there is no need for looking outside (such as looking to videos or enjoying other entertainments), but living always in underground structures may put at risk the psychological health of the colonists (claustrophobia), decreasing also their ability to assess distances when outside the outpost (difficulties in performing EVA tasks) and may be particularly bad in case one of the activities of the outpost is space tourism. Another problem is the construction of greenhouses, which should allow the light from the sun to enter for powering the plants' biological mechanisms."

As an alternative, Peroni suggests a design for a base that would provide its own shielding while maximizing access to the Martian landscape. This base would be transported to Mars aboard a vessel with sphere-shaped core (measuring about 300 meters (984 ft) in diameter) around which the hexagonal base modules would be arranged. Alternately, Peroni and his colleagues recommend creating a cylindrical core to house the modules.



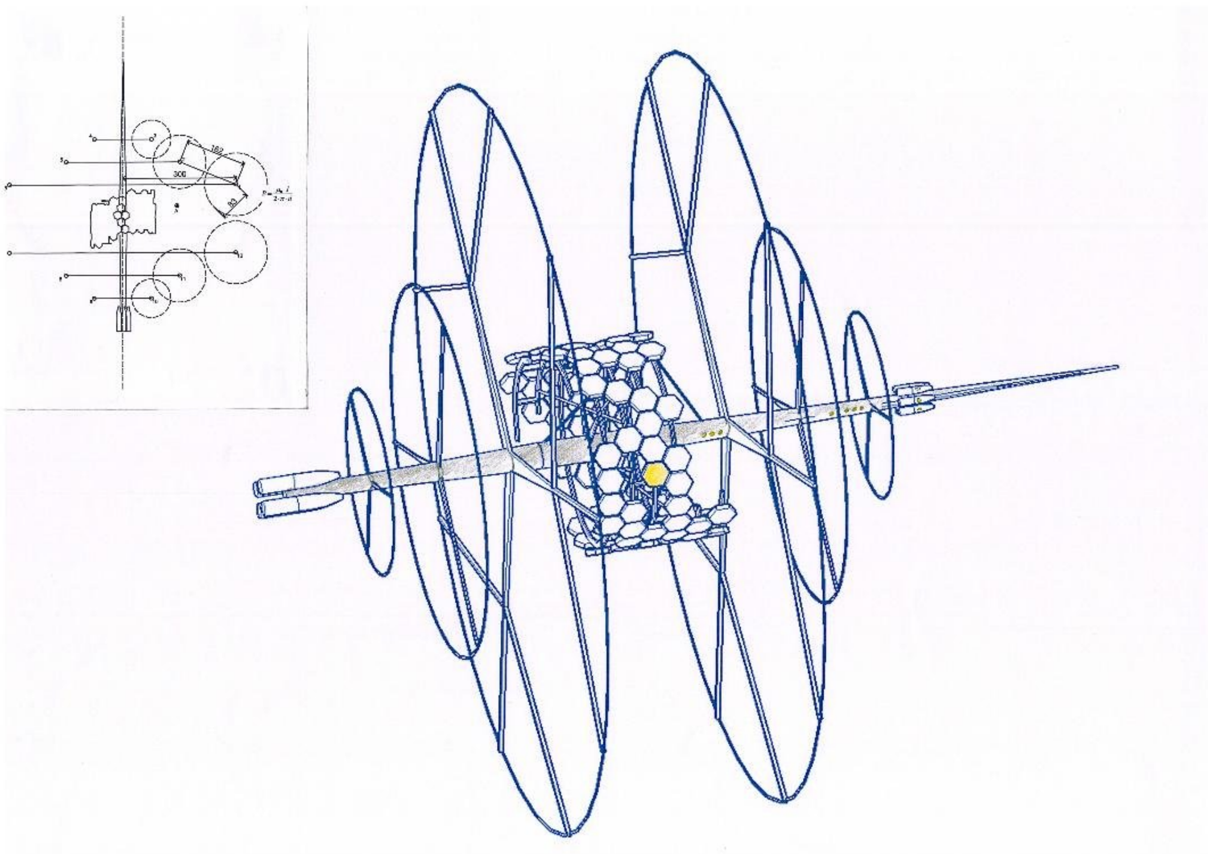
Artist’s impression of the central core of the spaceship, around which the modules will be attached for transport. Credit: Marco Peroni Ingegneria

This spaceship would transport the modules and inhabitants from Earth (or cis-lunar orbit), and would be protected by the same type of artificial magnetic shield used to protect the colony. This would be generated by a series of series of electric cables that would envelop the ship's structure. During the journey, the spaceship would also rotate around its central axis at a rate of 1.5 revolutions per minute in order to generate a force of gravity of about 0.8 g.

This would ensure that the astronauts arrived in orbit around Mars without having suffered from the degenerative effects of exposure to microgravity – which include muscle and bone density loss, compromised eyesight, decreased immune system and organ function. As Peroni explained it:

"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. These spacecraft have been developed 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 is easier to connect and aggregate the modules, which have similar shapes."

Once in Martian orbit, the ship-sphere would stop rotating to allow each element to detach and begin descending to the Martian surface, using a system of parachutes, thrusters and air resistance to slow down and land. Each module would be equipped with four motorized legs that would allow them to move around on the surface and connect with the other habitation modules once they arrive.



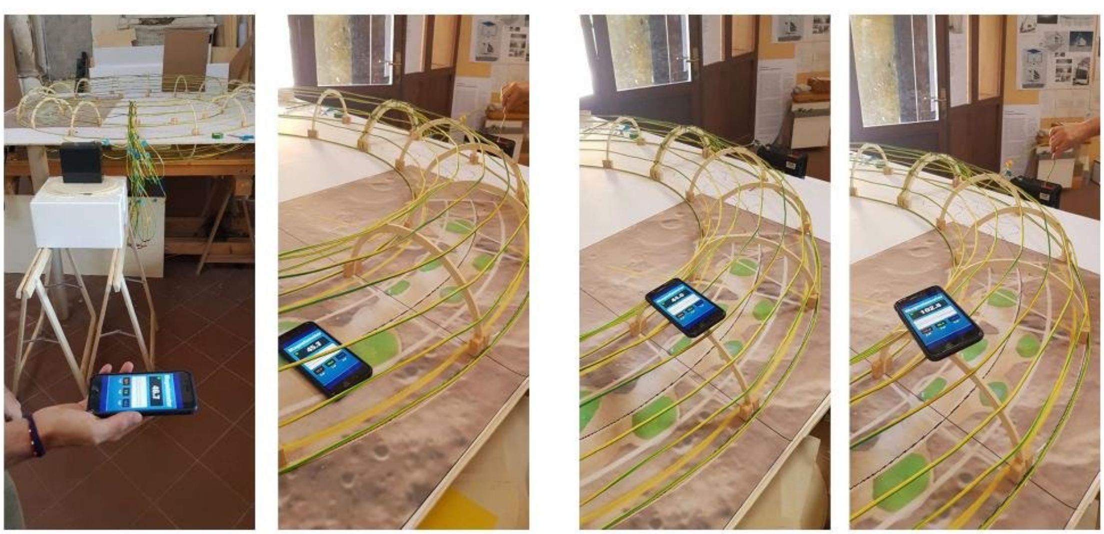
Artist’s impression of the spaceship that would transport the modular base to Mars. Credit: Marco Peroni Ingegneria

Gradually, the modules would arrange themselves in a spherical configuration under a toroid-shaped apparatus. Much like the one protecting the spaceship, this apparatus would be made of high-voltage electric cables that generate an electromagnetic field to shield the modules from cosmic and solar radiation. A spacecraft (such as SpaceX's proposed BFR) could also depart from the central core of the vessel, ferrying the future settlers to the planet.

To determine the effectiveness of their concept, Peroni and his colleagues conducted numerical calculations and laboratory experiments using a scale model (shown below). From this, they determined that the apparatus was capable of generating an external magnetic field of 4/5 Tesla, which is enough to keep the inhabitants safe from harmful cosmic rays.

At the same time, the apparatus generated an almost null magnetic field inside the apparatus, which means it would not expose the inhabitants to any electromagnetic radiation – and therefore presents no danger to them. Each module, according to Peroni's proposal, would be hexagon-shaped, measure 20 m (65.6 ft) in diameter, and would have enough vertical room inside to constitute a habitable space.

Each of the modules would elevated about 5 m (16.5 ft) above the ground (using their motorized legs) to allow the Martian wind to run off during sandstorms and prevent the accumulation of sand around the modules. This would ensure that the view from inside the modules, a key component to Peroni's design, would be unobstructed.



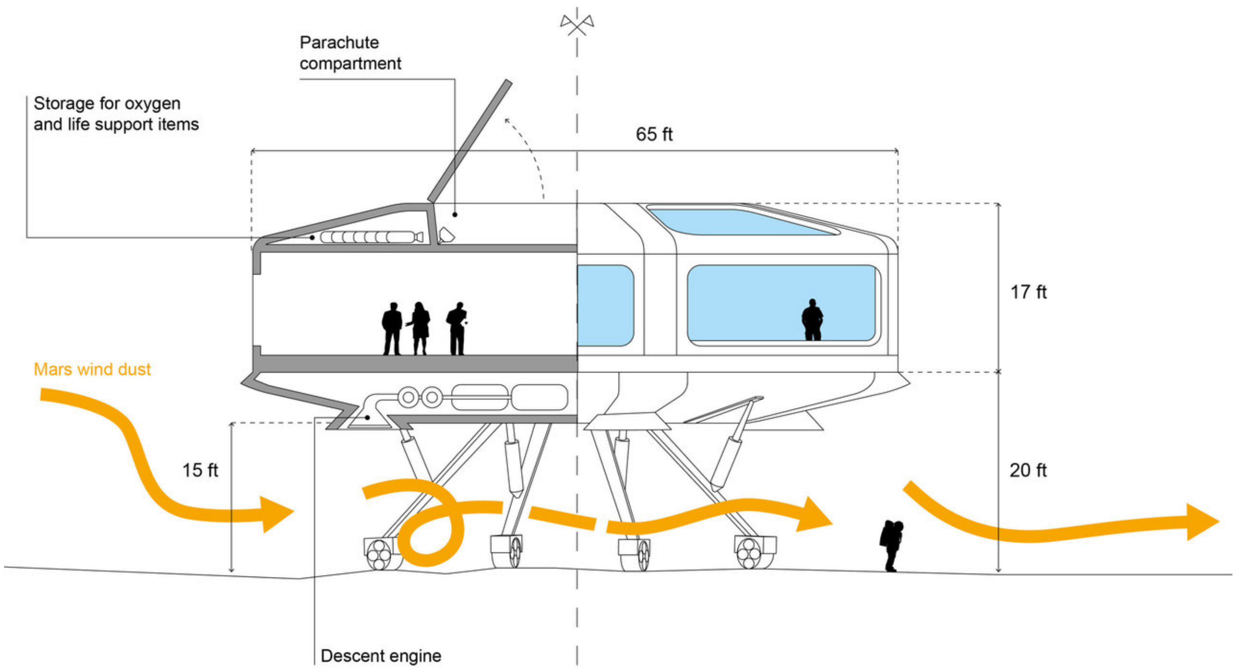
The scale model for the toroid-shaped electrical apparatus that would provide magnetic shielding to a Martian base. Credit: Marco Peroni Ingegneria

In fact, Peroni's proposal calls for the base to be open as much as possible to the surrounding landscape through windows and sky vaults, which would let the inhabitants feel more closely-connected to the environment and prevent feelings of isolation and claustrophobia. Each module would weight an estimated 40-50 metric tons (44-55 US tons) on Earth – which works out to 15-19 tons (16.5-21 US tons) in Martian gravity.

Some of the initial weight would include the fuel needed for the descent, which would be shed during the descent and mean the habitats were even lighter once they reached the surface of Mars. As with similar designs, each module would be differentiated according to their function, with some serving as sleeping quarters and others recreation facilities, green spaces, laboratories, workshops, water recycling and sanitation facilities, etc.

The final touch will be the building of a "technological axis," a walkable tunnel built above the ground where batteries, photovoltaic panels and small nuclear reactors would be stationed. These would see to the base's considerable electrical needs, which include the power necessary to maintain the magnetic field. Other elements could include garages and warehouses for exploration vehicles, as well as an astronomical observatory.

This proposal is similar in many ways to the Solenoid Moon-base concept that Peroni presented at least year's AIAA Space and Astronautics Forum and Exposition. On this occassion, Peroni proposed building a lunar base that consisted of transparent domes that would be enclosed inside a toroid-shaped structure consisting of a high-voltage cables.



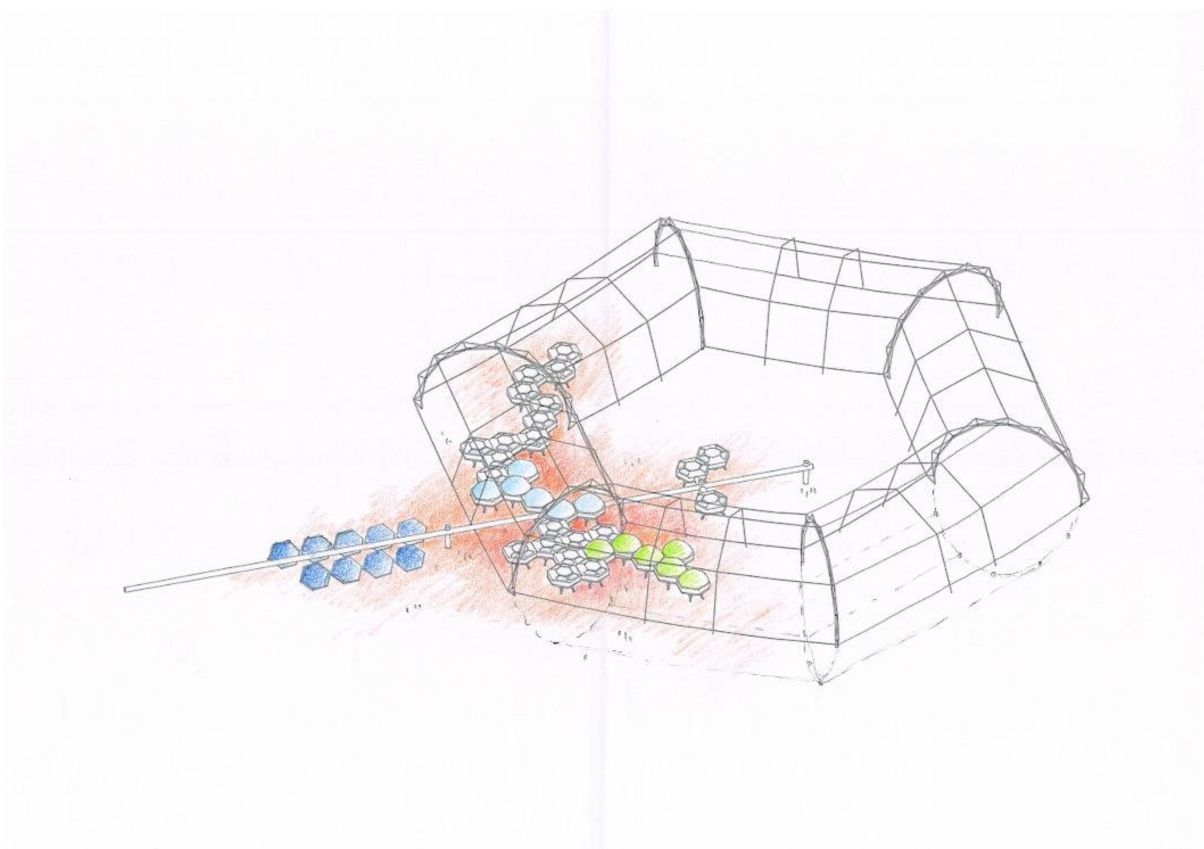
Artist’s impression of a single Martian module. Credit: Marco Peroni Ingegneria

In both cases, the proposed habitats are all about ensuring the needs of their inhabitants – which include not only their physical safety, but also their psychological well-being. Looking to the future, Peroni hopes that his proposals will foster more discussion and research into the particular challenges of building off-world bases. He also hopes to see more innovative concepts designed to address these.

"This preliminary research may encourage [the] future development of these theories and a deeper study on themes and topics covered in this contribution, that, why not, in the future will [allow] humans to realize the dream of living on Mars for long periods without being enclosed under heavy metal cages or dark rock caverns," he said.

It is clear that any settlements built on the Moon, Mars, or beyond in the future will have to be largely-self sufficient – producing their own food, water, and building materials in-situ. At the same time, this process and the act of daily living will be heavily dependent on technology. In the coming generations, Mars is likely to be the proving grounds where our methods for living on another planet are tested and vetted.

Before we start sending humans to the Red Planet, we need to make sure we put our best methods forward.



Artist's impression of the modular base's layout. Credit: Marco Peroni Ingegneria

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