TECHNOLOGY FOR TERRAFORMATION OF MARS, OTHER PLANETS AND NATURAL SATELLITES

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ABSTRACT

This paper presents principles and technologies for terraformation of Mars, other planets and natural satellites. It is certain that our civilization must expand within the solar system. Mars is the closest planet to Earth. However, in the future our civilization will probably colonize other planets and also natural satellites of other planets.
In the case of Mars, a lot of energy and labor will be required because this planet lacks a sufficiently dense atmosphere and is much colder than Earth. The new technology presented in this paper makes easier the terra-formation of this planet, by creating an Earth-like atmosphere and heating inhabited areas of planet with additional solar light.
A space system composed of two opposite parabolic mirrors (large and small) having a common focal point can be used for creating a respirable atmosphere on planet. The concentrated light beam generated by this system can be thousands of times more intense than sun light.
The system can be placed either on a Sun synchronous orbit around Mars (being oriented continuously with the large parabolic mirror to the Sun) or on Mars's orbit around the Sun (in this case the system follows the planet at a small distance). When the concentrated light beam is directed to the Martian ground, the local soil temperature reaches thousands of degrees Celsius and the matter melts vaporizes or separates in constitutive elements.

KEY WORDS: Mars terraformation, natural satellites terraformation

NOMENCLATURE

E_{Es}, average irradiance at earth's surface, [W/m^2]
E_M, irradiance in proximity of Mars, [W/m^2]
P, power, [W]
r, radius, [m]
R, reflectivity, dimensionless

1. INTRODUCTION

In our days, our civilization has begun the expansion into the solar system. The first target is Mars. After Mars, expansion will continue to other planets and natural satellites.
The first Martian colonies will be housed in shelters with controlled atmosphere and protection against radiations and green houses for plant cultivation.
The second stage is terraformation, i.e. transformation of Mars into an Earth like planet. This option requires the creation of a dense Martian atmosphere, generation of an artificial magnetic field for protection against radiations and heating of large areas of planet's surface.
The next chapters of this paper present an affordable technology which can be applied at planetary scale for terraformation of planet Mars and other planets and natural satellites from our solar system.

2. DESIGN OF SPACE SYSTEM-INSTRUMENT OF TERFORMATION

In a precedent paper, the authors presented the idea of a space system used for protecting Earth against asteroids. [1] That space system can be used as an instrument for terraformation of Mars, other planets and natural satellites, too.
For a better understanding of this terraformation method, the main components of space system are presented in fig. 1. The system is composed of two parabolic mirrors (large and small) placed face to face, having a common focal point, F and coincident axis.

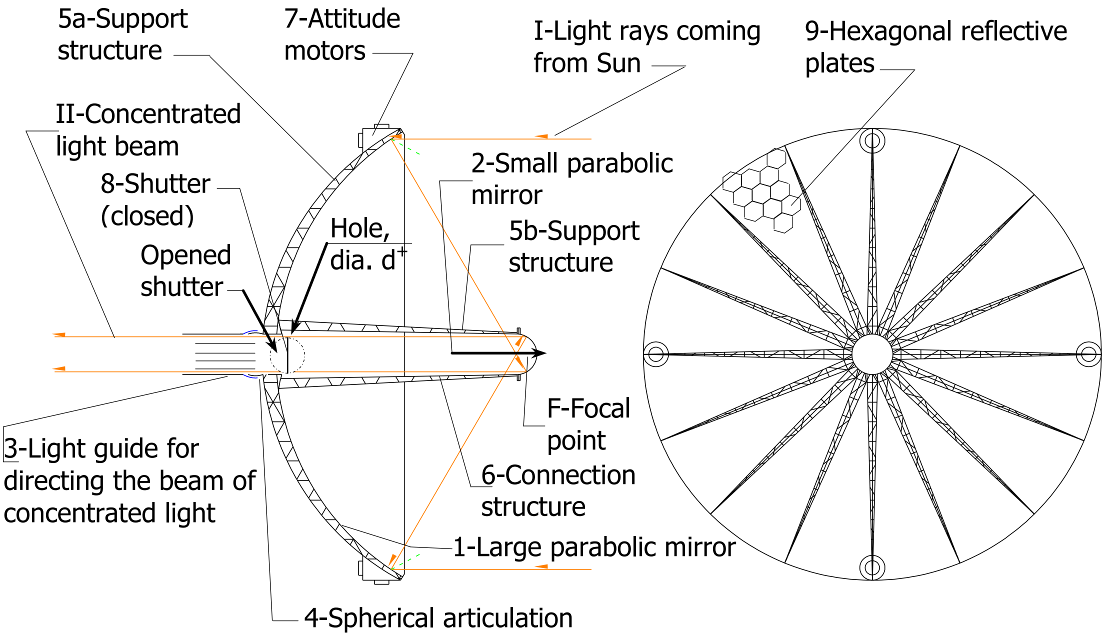

Figure 1: Design features of space system

The components of system and their roles are:
1-the large parabolic mirror-collects solar light
2-the small parabolic mirror concentrates the light rays in a beam passing through the hole having dia. d^+ placed in the large parabolic mirror
3- Light guide - directs the beam of concentrated light-it has a honeycomb reflective structure being articulated onto the large parabolic mirror with spherical articulation 4
4- Spherical articulation-permits targeting the light guide and concentrated light beam toward a point on Mars's surface
5a-Support structure-it is the support structure of the large parabolic mirror
5b-Support structure-it is the support structure of the small parabolic mirror
6-Connection structure-connects the two parabolic mirrors
7-Attitude motors-control the system attitude
8-Shutter-opens or closes the concentrated light beam access to the light guide
9-Hexagonal reflective plates-form the large parabolic mirror being placed on support structure 5a and 5b
The large and small parabolic mirrors are made of thin reflective plates which are manufactured from composite material (graphite fiber or graphene basis) and covered with a 5 microns gold film. The gold film confers a good reflectivity of solar light and graphite fiber allows quick transmission of heat through conductivity and cooling of mirrors through radiation. The reflective plates 9 are placed on support structure 5a and 5b. When the diameter of small parabolic mirror is under 5m, this mirror can be made as a single piece.
The system works as follows:
The large parabolic mirror is oriented with the concave surface to the Sun. The light rays I (kept parallel to each other with high accuracy) coming from Sun (visible, infrared and ultraviolet light) are captured and concentrated by the large parabolic mirror in its focal point, F. The light rays are then reflected by the small parabolic mirror as parallel rays directed along the common axis of both mirrors (this is possible because the parabolic mirrors have the same focal point, F, and coincident axis).If the shutter is opened, the concentrated light beam passes through the hole 'd^+' placed in the center

of large parabolic mirror. If the shutter is closed, the concentrated light beam id reflected back to the small parabolic mirror, then to the large parabolic mirror and finally to the Sun. In this situation the system is shut off.
When the shutter is opened, the concentrated light beam enters the light guide tube made of fine reflective honeycomb cells. Being articulated by the large parabolic mirror with a spherical articulation, the light guide can direct the concentrated light beam to the planet's surface. When the light guide and reflective honeycomb have a pyramidal shape, the light beam can be concentrated onto a very small area on planet's surface where temperature can reach very high values, theoretically infinite when the area of impact on surface is reduced to a point.
The system can be built on an orbit around Earth. Transportation of system's components in space can be assured by rockets as presented in fig.2. Robots can assemble the system on orbit (like NASA's Spiderfab) - fig.3. Building such a large structure in space is possible because the gravitational force of Earth is balanced by the inertia force generated by rotation on geocentric orbit. After building the system on geocentric orbit, it can be accelerated by busters for placement on the Mars's orbit around Sun.

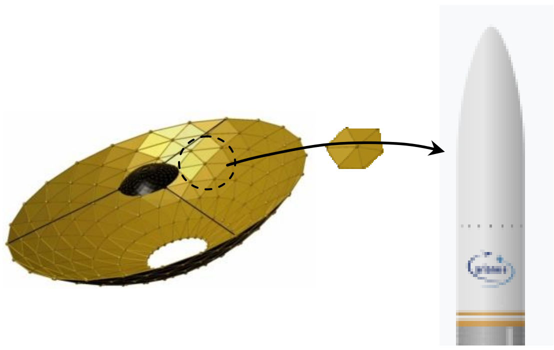

Figure 2: Transportation of system in space

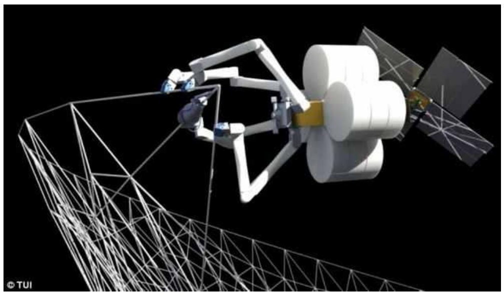

Figure 3: NASA's Spiderfab robot

3. THE POWER OF SPACE SYSTEM

The maximum power of such a system depends on solar power collected by the large parabolic mirror. Table 1 presents the total collected solar power, P_{lpm}, and the total available power, P_e as a function of the radius of large parabolic mirror, r_{lpm}.
[Notes: The average solar irradiance on orbit of Mars was considered E_M = 590 Wm^{-2} (which is about 44% of irradiance on an orbit around Earth); the average reflectivity coefficient of gold plated mirrors was considered R=0.98]

Table 1-Power of system function of radius of large parabolic mirror

Case no.	**Radius of large parabolic mirror, r_{lpm} [m]**	**Collected solar power, P_{lpm} [MW]** (irradiance was taken E_M=590 W/m^2)	**Available power P_a [MW]** (Reflectivity coefficient was taken R=0.98 for gold)
1	50	4.6	4.5
2	60	6.7	6.5
3	70	9.1	8.9
4	80	11.8	11.6
5	90	15.01	14.7
6	100	18.5	18.2
7	200	74.1	72.7
8	400	296.6	290.6
9	500	1068.14	1025.8

4. The chemical composition of Mars

Mars's color is red because Martian surface is a thick layer of oxidized iron dust and rocks of the same color. [2] Practically most of Mars's surface is covered by this dusty layer. Elementary sodium, potassium, chloride and magnesium can also be soil components.
Under the layer of dust, there is a crust (about 50 km thick) composed of volcanic basalt rock. Composition of basalt is 45…55% SiO_2, 17…22% MgO, approx 14% Al_2O_3, 5–14 % FeO, approx. 10% CaO, other oxides and elements.
This crust is a single piece, i.e. not formed from tectonic plates like Earth's crust.
Under the crust there is an inactive mantle having consistency of a hot paste and probably made mainly of silicon, oxygen, iron, and magnesium. The thickness of this mantle is probably of 5,400 to 7,200 km.
Under the mantle, Mars probably has a solid core with an estimated diameter of 3000…4000km made of sulfur, iron and nickel.
Due to the fact that the core is not moving, Mars has no magnetic field. For this reason, Mars surface is not protected from radiations as Earth surface.
On Mars, water exists as ice inside soil and at poles because Mars is colder than Earth. The average temperature ranges between minus 125 ºC near poles during winter up to 20 ºC near the equator.

4. CREATING A THICKER ATMOSPHERE ON MARS

The present Mars atmosphere is very thin and has the following composition: [3]
Carbon dioxide (CO_2) - 95.32%
Nitrogen (N_2) - 2.7%
Argon (Ar) - 1.6%
Oxygen (O_2) - 0.13%
Carbon Monoxide (CO) - 0.08% and other minor components (Ne, NO, H_2O, Xe).
The goal is to make Martian atmosphere thicker and enriched in oxygen and nitrogen.
When the concentrated light beam is targeted on Mars surface (fig.4), very high temperatures are reached. If the honeycomb cells of light guide have a pyramidal shape, the whole energy can be focused onto a very small area or even point-like in which case the local temperature can be theoretically infinite.
At very high temperature, the FeO which forms the dusty layer of Mars surface and the other oxides which are found in basaltic crust composition (SiO_2, MgO, Al_2O_3, CaO) can be separated into elements or in other oxides. Finally, all the oxides are decomposed into oxygen and other elements.
When the concentrated light beam targets the layer of dust, first the FeO is decomposed at temperature t=575 ºC according to equation (1):

$$4FeO \rightarrow Fe + Fe_3O_4 \qquad (1)$$

The oxide Fe_3O_4 is called 'magnetite'. It was demonstrated that at the temperature of melting point (1597 ºC) + 300 ºC, the magnetite is decomposed in Fe and oxygen. [4,5]Iron atoms, being heavier than atoms of oxygen remain on the planet surface. The oxygen atoms recombine in O_2 molecules enriching Martian atmosphere with oxygen.
After the decomposition of FeO from the dust layer, the concentrated light beam begins to decompose the crust magnetite located under the dust layer.
Most of oxides composing magnetite are extremely heat resistant and decompose at very high temperatures:

$$2Al_2O_3 \xrightarrow{t>2980\,°C} 4Al+3O_2 \qquad (2)$$

$$2MgO \xrightarrow{t>3600\,°C} O_2+2Mg \qquad (3)$$

$$SiO_2 \xrightarrow{t>2230\,°C} O_2+Si \qquad (4)$$

t >2850 ° C

$2CaO \quad \text{---->} O_2 + 2Ca$ (5)

These temperatures are easily obtained in the point where the concentrated light beam impacts the crust. This is the simplest technology for generating oxygen for Martian atmosphere. For developing Earth-like atmosphere nitrogen is necessary because the current concentration of this gas in mars atmosphere is only 2.7%. This element is essential for life. Evidence of indigenous nitrogen was found in sediments and Aeolian deposits on Mars. [6] It is possible to release nitrogen captured in those sediments and Aeolian deposits heating them with the presented space system.

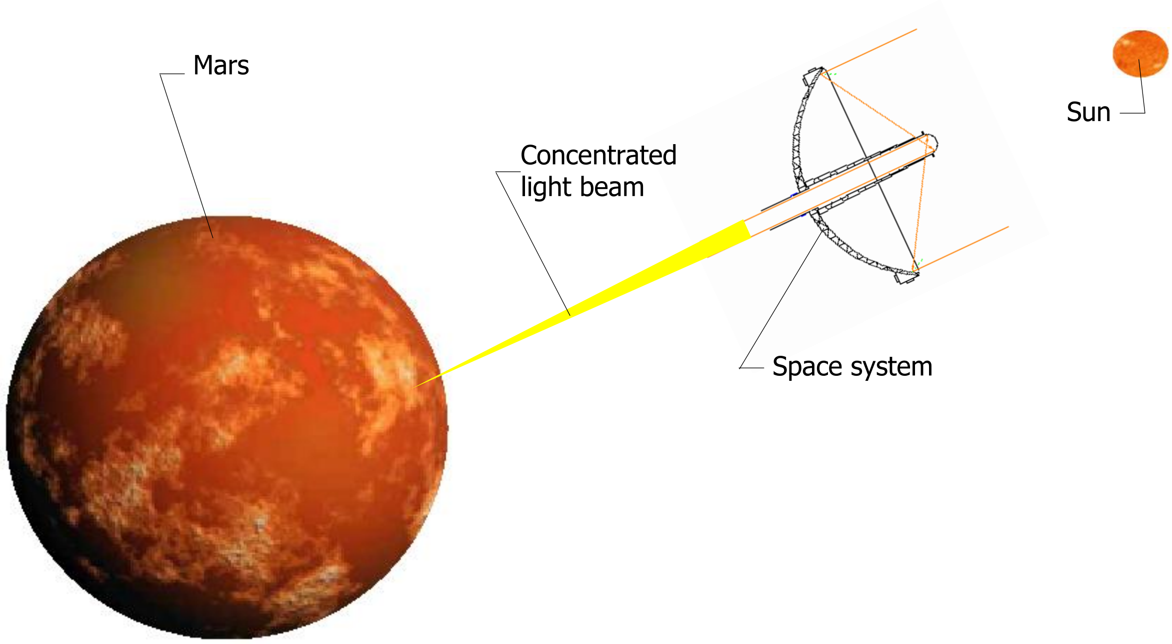

Figure 4: Generating of Mars's atmosphere

5. LOCAL HEATING OF MARS SURFACE

Mars is a cold planet. Using more space systems placed on the orbit of Mars around Sun, heated zones can be created in the equatorial area of planet (fig.5). This time the honeycomb cells of light guide are slightly divergent conditioning the local irradiance on Mars's surface to be equal to the average irradiance on Earth's surface (E_{Es}=1000 W/m^2).In this way, local temperature in zones where intense human activities occur can be increased to an appropriate value which is close to the average temperature of Earth's surface.

6. CREATING AN ARTIFICIAL MAGNETIC FIELD ON MARS FOR PROTECTION AGAINST RADIATIONS

Mars does not have a magnetic field like Earth because its core is solid and does not rotate. For this reason the planet's surface is not protected against radiations like terrestrial surface In the case of Earth, radiations like solar wind-high speed particles generated by Sun are kept away by the magnetic field of Earth. [7]
The magnitude of magnetic field of Earth created by the rotating iron core of Earth has the intensity of 25 to 65 microteslas (0.25 to 0.65 Gauss). [8]
The magnetic field of Earth is equivalent with an inverted magnetic dipole as shown presented in fig.7.
It is impossible to manufacture a single and strong dipole penetrating the entire planet Mars. However, as it was shown in equation (1), magnetite (F_3O_4) can be easily created through decomposition at low temperature (575ºC) of FeO which is present in the dust layer existent on Mars's surface.

The magnetite can be easily magnetized in a strong magnetic field created by an electromagnet being transformed into a 'Lodestone' like magnet.
Such natural magnets can be created and incorporated in high quantities in Mars's ground for creating magnetic fields over populated areas. The south poles of magnets must be placed normal to the rotation axis of planet in equatorial area and oriented to the exterior (fig.8).

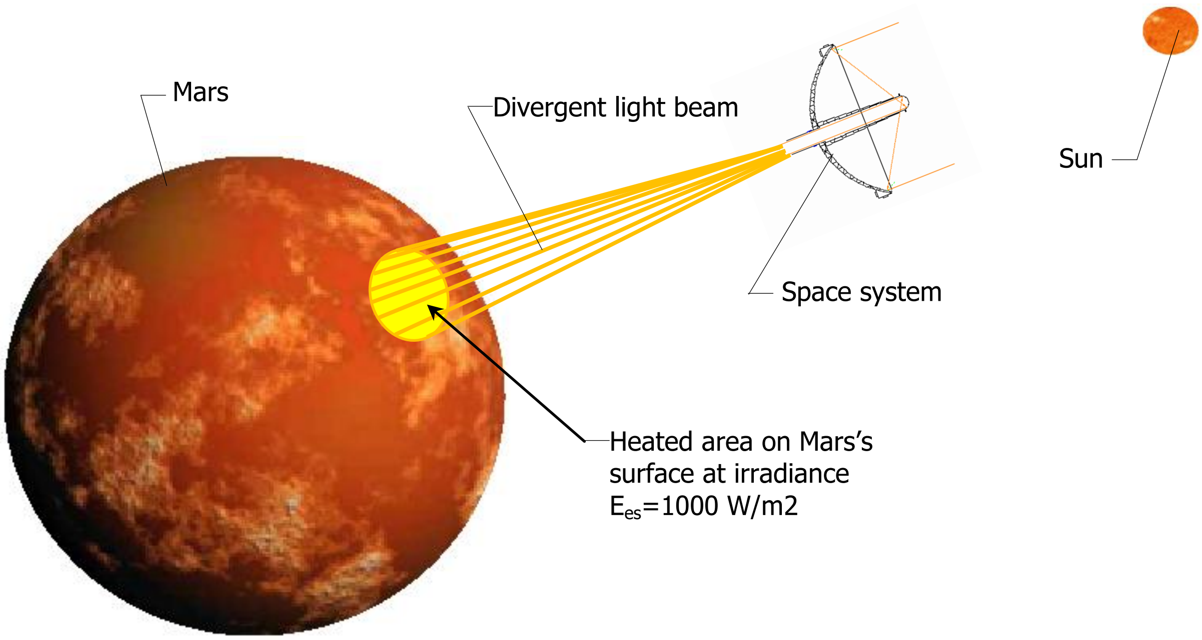

Figure 5: Additional heating of surface areas on Mars

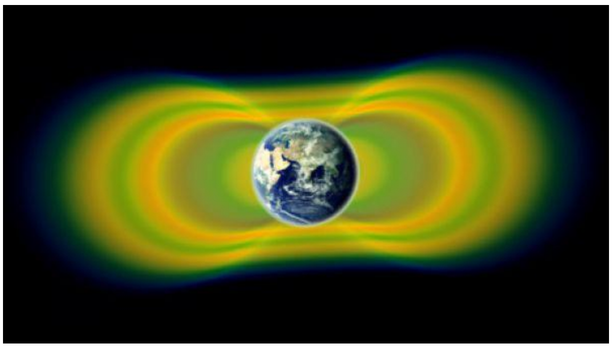

Figure 6: Van Allen Belts

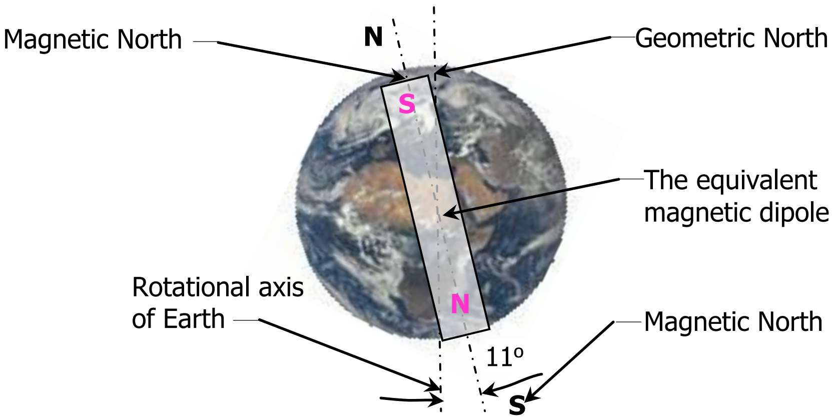

Figure 7: Positioning of equivalent magnetic dipole for Earth

In order to create a strong magnetic field, the individual magnets must be stacked in large pillars which are buried in the ground. This is necessary because the permanent 'Lodestone' like magnets create a magnetic field spanning a smaller region than the magnetic field of Earth and the most populated areas should be placed in the equatorial region of Mars.

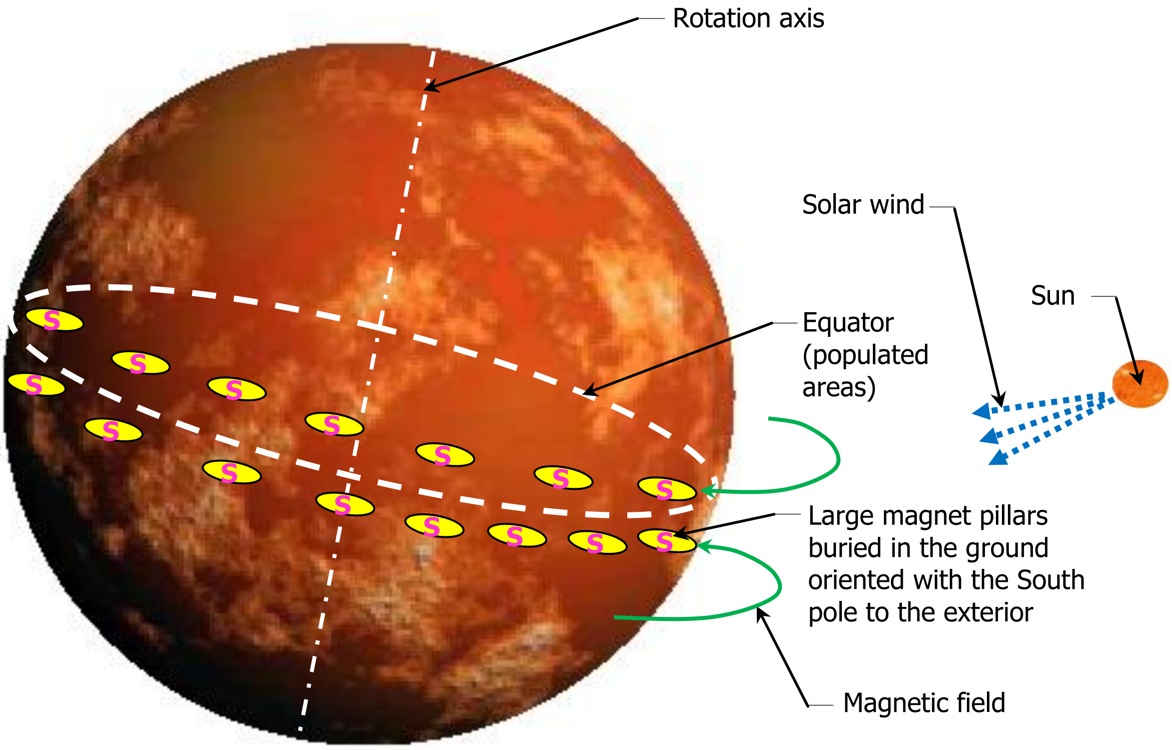

Figure 8: Generating of magnetic field of Mars

7. Terraformation of Venus. Mercury and other natural satellites found in the solar system

Environmental conditions on Venus are extremely hostile. Venus's atmosphere is composed mostly of carbon dioxide with floating clouds of sulphuric acid and sulphur dioxide.
Surface conditions on Venus's surface are difficult: temperature is around 450 °C at equator and atmospheric pressure is about 90 bars at ground level. Water in any form is absent.
In addition, unexpectedly, the magnetic field of Venus is just 0.000015 times Earth's field. [9]
For this reason, terraformation of Venus must be a long term goal which could take hundreds of years.
The first hope is given by carbon dioxide, sulphuric acid and sulphur dioxide eating bacteria. These bacteria must be artificially grown to resist conditions on Venus surface. Consumption of carbon dioxide atmosphere will lead to decreasing pressure at planet surface and to the reduction of temperature due to the dampening a of green house effect. Only after that a suitable atmosphere could be created using the space system presented in this paper.
Teraformation of Mercury is a difficult process, too, due to the vicinity of Sun. For this planet and some natural satellites including the moon, Europa of Jupiter and Enceladus of Saturn terraformation of underground space should be considered. This location must be considered for protection against radiations, heat or cold. In these cases, large spaces should be created underground using controlled atomic explosions. The spaces should be illuminated by artificial light. Circuits of water and air should also be created.

6. CONCLUSIONS

▪The space system composed of two parabolic mirrors placed face to face and having a common focal point can be used for generating atmosphere on Mars and local heating its surface.

▪Oxygen can be produced through the ecomposition of oxides from the dust layer and crust. Nitrogen can be produced through separation of this gas from existing sediments and Aeolian deposits.

▪Large quantities of magnetite (F_3O_4) obtained through heating of FeO at 575 ºC melted in regular pieces which can be magnetized for creating permanent magnets. Large pillars buried under ground composed of multiple magnets oriented with the South poles to the exterior of planet along the equator create an equatorial protection against radiation (solar wind particles).

▪The first stage of Venus terraformation is the use of artificial bacteria which can tolerate up to 90 bar and 450 ºC (conditions at planet's surface) and consume CO2, sulphuric acid and sulphur dioxide and reduce pressure and temperature by dampening the green house effect.

▪Terraformation of Mercury and other natural satellites as Moon, Europa and Enceladus must be limited to the creation of large underground spaces using atomic explosions.

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