Terraforming of planet Mars

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There have been presenting a lot of methods and technologies (mirrors on the Mars Orbit, strong magnetic field surrounding Mars etc.) how to create suitable atmosphere on planet Mars; the most effective way were developed by Bohumir Stedron (Stedron, 2004). The new approach is based on sending Phobos and Deimos to the Mars frozen subsurface areas. This article presents this new approach to the terraforming of the planet Mars, using current technologies.

How to Adapt Atmosphere of Mars in Near Future

Contemporary state of telecommunication development enables us to drive spacecrafts on Mars orbit or Mars surface very precisely. Recent successful landing of Curiosity rover on Mars is serious evidence of it. The only limitation is light velocity. Every signal from the Earth to Mars or a signal in opposite direction flights around 15 minutes depending on the actual distance of Mars. However, this limitation is solved with automatization of more complicated tasks in most situations.

The planet Mars is an attractive destination for various spacecrafts. Now, the spacecrafts are automatic, and they obtain data about Mars surface, physical processes, Mars weather, and indirectly even about the interior of Mars. However, the humankind will not be satisfied with this state. It will colonize Mars in coming decades with great probability. The specific date of manned mission to Mars is constantly postponed due to many problems. Sparse atmosphere of Mars and low temperature on Mars surface belong to them.

Particular projects try to increase Mars atmosphere density with different methods, for example microorganisms, vegetation, mirrors (in orbit around Mars). Mars has giant water reserves in subsurface frozen ocean with dimensions 800×800 km, discovered in 2005. We can use it for our benefit.

Driven Fall of Mars Satellites to Mars Surface

It seems that the fastest way to make the atmosphere denser is to transfer Mars satellite Phobos or Deimos (or both) to descending trajectory and cause the fall of the satellite to Mars. If we aim the satellite or both satellites just to that ocean, big amount of water will sublimate, and surface air pressure and temperature will increase. The highest temperature increase will happen on the place of the fall; however, consequences of the fall will affect the whole planet. Global higher temperature will probably also cause evaporation of frozen carbon dioxide. Although part of carbon dioxide and water steam escape Mars or will be dissociated by solar radiation, the process will be relatively slow. For the first several decades or centuries after the fall, the atmosphere will stay denser than now. This fact will help mankind with Mars colonisation.

The crucial question is how to change trajectory of Mars satellite to descending trajectory. Probably the simplest method is to use rocket motors. Contemporary Saturn V rocket has a thrust of 34 meganewtons (first stage) for 150 seconds. It can be presumed that propulsion unit much more powerful than contemporary Saturn V will be available after 2050.

Let's analyze the problem closer.

Both Mars satellites circulate in near circle orbits almost sharp in Mars equator plane. Parameters of the satellites and their orbits are following:

satellite	Phobos	Deimos
orbital radius r_0 [km]	9 380	23 460
orbital velocity v_0 [km/s]	2.138	1.352
orbital period T [day]	0.319	1.262
mass m [kg]	10.659×10^{15}	1.476×10^{15}

The energetically least demanding way how to manage the fall of a satellite to Mars, is to decrease the original orbital velocity v_0 to a new velocity v_1 so high, to the satellite enters a new, elliptic orbit with its farthest point in a distance of the original circle orbit $r_1 = r_0$ and with the narrowest point in distance r_2 which is equal to Mars radius. Mars radius is 3402.5 km. We start from energy conservation law

$E_{k1} + E_{p1} = E_{k2} + E_{p2}$,

where $E_{k1} = ½\, m\, v_1^2$ is kinetic energy of the satellite after slowing down in the farthest point of the new orbit,

$E_{p1} = -\,\kappa\, m\, M\, /\, r_1$

is potential energy of the satellite in the farthest point of the new orbit, $E_{k2} = ½\, m v_2^2$ is kinetic energy in the narrowest point of the new orbit (it means in distance of Mars radius from the center of Mars) r_2 , and

$E_{p2} = -\,\kappa\, m\, M\, /\, r_2$

is potencial energy in the narrowest point of the new orbit (it means in distance of Mars radius from the center of Mars) r_2. Next, we use law of angular momentum conservation which can be written is scalar form

$r_1\, m\, v_1 = r_2\, m\, v_2$,

so

$r_1\, v_1 = r_2\, v_2$.

We considered the mass of Marsu $M = 6.4185\times10^{23}$ kg as much greater than the masses of Mars satellites. However, Mars also rotates, and the direction of Mars rotation is the same as direction of satellites orbital movement. One Mars rotational period is 24 h 52 min long. Rotational velocity on Mars equator is $v_{rot} = 0.239$ km/s. It is necessary to substract this velocity from the satellite velocity in the narrowest point v_2. Velocity of tangential fall is $v_2‘ = v_2 - v_{rot}$. It would be enough to slow down the satellites a bit less. The narrowest point would not be on the surface but somewhere above – but in Mars atmosphere, and braking effect of the atmosphere would slow down the satellite so much that the satellite would fall to Mars after several circuits.

Resultant velocities are in following table

satellite	Phobos	Deimos
v_1 [km/s]	1.559	0.680

v_2 [km/s]	4.298	4.689
v_2‘ [km/s]	4.059	4.450
E_{k2}‘ [J]	8.781×10^{22}	1.461×10^{22}

E_{k2}‘ is “effective” kinetic energy of the satellite movement in the moment of the fall to Mars. We can suppose that most of this energy transforms to heat (less part affects deformation and destruction of surface rock on Mars, rotation velocity can negligibly change, etc.).

Mars atmosphere will be thicken mainly by carbon dioxide CO_2 (it constitutes 95% of planet atmosphere already now) and water steam H_2O which will sublimate into atmosphere in a big amount.

Exact amount of H_2O on Mars in unknown and estimations are changing according to new explorations of cosmic space probes. Now, the amount of H_2O on Mars is being estimated to 5×10^6 km^3 (5×10^{18} kg) [2]. Most of water ice is located in polar caps but approximately 6×10^4 km^3 (6×10^{16} kg) of water ice is situated in middle latitudes (as a part of permafrost). 3×10^{-2} km^3 (3×10^{10} kg) sublimates to the atmosphere and deposits back to the ground seasonally. Water nearly cannot exist in liquid state on Mars because average pressure on Mars is only 0,610 kPa. This pressure is approximately equal to pressure in Earth’s atmosphere in height of 30 km over sea level.

Average temperature on Mars is −63 °C. If the frozen ocean should be sublimated after the fall, the low temperature ice must be heated to melting temperature 0 °C first. Then latent heat of sublimation must be given (latent heat of melting, heat necessary to warming to boiling temperature, and latent heat of boiling respectively).

Next leather which will be disengaged to atmosphere is CO_2, which exists in solid state in polar areas. A part of CO_2 sublimates and deposits as a consequence of seasonal rhythm. CO_2 sublimates by −78 °C temperature.

If all kinetic energy of both satellites transforms to heat this heat would be enough to warming and sublimation of 3.308×10^{16} kg of H_2O, it means approximately 0.7% of total water on Mars. It remains as a question, how high steam would spread. Mars atmosphere consists of three main layers: low (to height 45 km), middle, where jet stream flows (45 – 110 km), and upper (over 110 km).

Layer height	45 km	10 km	5 km
Density of water steam	0.005 kg/m^3	0.223 kg/m^3	0.436 kg/m^3

The density of air on Earth is 1.28 kg/m^3.

However, it is a great unknown variable what would really happen. Surely, not all kinetic energy of the moons would be utilized to sublimation of H_2O. Also CO_2 would sublimate partially. Bigger amount of CO_2 and H_2O in atmosphere would strenghten greenhouse effect, which would lead to further temperature growth and further sublimation, especially CO_2. Till now, we have only a very rough imagination of Mars interior (the Mars InSight space probe which should explore it will launch in 2016). The fall of Mars satellites could cause volcanic activity which would thicken Mars atmosphere more.

Let's the Sun to Work

The whole project of frozen ice ocean sublimation could be realized alternatively without throwing down Phobos and Deimos to Mars surface. Ice ocean is hidden under regolith layer about only about 1 m thick. [3] If we are able to mine it and transport anywhere the 800×800 km large ice ocean would sublimate as a consequence of solar radiation. This "mining version" could be also less energetically demanding. But it would be also slower and would contend with the problem of dust storms which would cover the uncovered ice areas with dust again. Also ice sublimation would be slower.

The development of convenient bulldozers for Mars could be significantly simpler that development of stronger rocket motors. Successful rover Curiosity which is as big as two cars gives hopes that "heavier equipment for Mars" can be developed relatively soon, maybe in 10 years.

In any case, this version of the project would be very demanding. Such a large project of coordinated transport of big amount of soil was not realized on the Earth.

Conclusion

The atmosphere on Mars is relatively thin and is composed mostly of carbon dioxide (95.32%). There has been interest in studying its composition since the detection of trace amounts of methane, which may indicate the presence of life on Mars, but may also be produced by a geochemical process, volcanic or hydrothermal activity.

The atmospheric pressure on the surface of Mars averages 600 pascals (0.087 psi), and ranges from a low of 30 pascals (0.0044 psi) on Olympus Mons's peak to over 1,155 pascals (0.1675 psi) in the depths of Hellas Planitia. This compares to Earth's sea level pressure of 101.3 kilopascals (14.69 psi), making the average surface pressure on Mars about 0.6% of Earth's mean sea level pressure. Mars atmospheric mass of 25 teratonnes, compares to Earth's 5148 teratonnes. However, the scale height of the atmosphere is about 11 kilometres (6.8 mi), somewhat higher than Earth's 7 kilometres (4.3 mi). The composition of the Mars atmosphere is 95% carbon dioxide, 3% nitrogen, 1.6% argon, and contains traces of oxygen, water, and methane, for a mean molar mass of 43.34 g/mol. The atmosphere is quite dusty, giving the Martian sky a light brown or orange colour when seen from the surface; data from the Mars Exploration Rovers indicate that suspended dust particles within the atmosphere are roughly 1.5 micrometres across.

The presented article demonstrates the approach how to change the atmosphere of Mars towards the Earth atmospheres parameters.

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