Shri Guru Gobind Singhji Institute of Engineering and Technology
Vishnupuri, Nanded (Maharashtra State) INDIA PIN 431606
Government Aided Autonomous Institute DTE Code: 2020
NAAC Accredited institute GRADE B++, CGPA 2.91 (2020 -2025)
Vision Statement: Education of Human Power for Technological Excellence

An essay on

Colonization of Mars

Vedant Nitin Dahake

January 2023

Abstract

What is the colonization of Mars? Why we chose only Mars and not any other planet? What is the current status of the missions? What is the probable timeline for this mission? What are the stakes? Is it really necessary? What potential does colonizing Mars hold? Many more questions are going to be answered in this essay. It starts from the basis of the colonization of mars mission through the whole process and tentative timelines. All the way to discussing the hurdles which are coming up and will come up during this mission. Discussing some ways to tackle them. Checking if this mission is worth it, economically, and some other possible solutions to the need for which humans are going to Mars.

Introduction

With the rapidly changing climate of the earth, people are starting to worry about the consequences that would come out of it and the survival of humans. To ensure the survival of our species colonizing other planets is important. Colonizing other planets and setting up bases there, has always been a great ambition of humans. All are eagerly waiting for the moment when humans will officially be declared as an interplanetary species. This will inspire a new generation of space explorers. Going to Mars is not only necessary for science but also politics. The first one to reach Mars would establish their political and economic leadership. The first step in achieving that ambition starts with going to a red-colored neighbor called Mars. Humans need to start the interplanetary species journey with the red planet first. The prospect has garnered interest from public space agencies and private corporations and has been extensively explored in science fiction writing, film, and art. Mars is close to the earth. It receives a decent amount of sunlight and has all the necessary metals and minerals to not only support and thrive life but could spark a new kind of human evolution. To date, no human has ever set foot on Mars, and there have been no return missions, rovers and orbiters have researched the planet extensively. Some private corporations are actively working on a mission to send humans to Mars and bring them back to earth.

Since the 20th century, there have been many proposed missions to the red planet by both government and private agencies like SpaceX, and Blue Origin. The leading corporation in this race to Mars is 'SpaceX' owned by entrepreneur 'Elon Musk'. The corporation was formed with the primary motive of sending humans to Mars. They made and tested a re-useable rocket in the year 2017 and are actively working on their launch vehicle named 'Starship'. Elon has made many predictions including landing the first cargo Starship by the year 2024 and 2 crewed Starships by 2026 (figure 1). Commitments to establish permanent settlements have been made by public space agencies like NASA, ESA, Ros Cosmos, ISRO, and the CNSA, among others, and private organizations like SpaceX, Lockheed Martin, and Boeing. At the February 2017 World Government Summit, the United Arab Emirates announced a plan to establish a settlement on Mars by 2117, led by the Mohammed bin Rashid Space Centre.

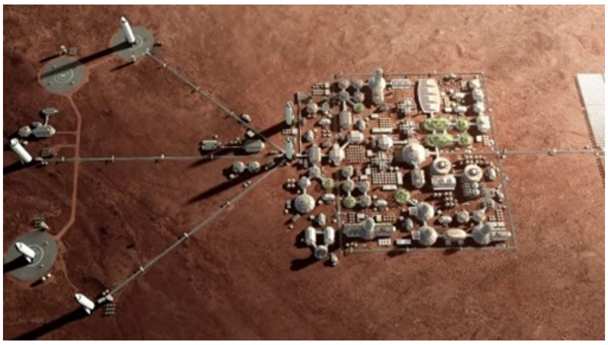


Figure 1: Proposed Mars base

Why Mars?

This is probably one of the big questions which are on the minds of people. Why did we only choose Mars? Why not other planets like Venus or moons like our moon or Titan? At an average distance of 140 million miles, Mars is one of Earth's closest habitable neighbors. Mars has abundant minerals and metals, has a gravity of 38 that of earth, and has potential water with ice caps being at the poles (figure 2). Colonizing Mars gives an advantage in the asteroid mining race as it is closer to the asteroid belt. The day on Mars is about 40 minutes larger than on earth. Well, then why not Venus, our moon, or

Titan was chosen, and why only Mars? Venus is a bit further from the earth. The atmosphere is 100 times dense than that of the earth and is filled with carbon dioxide, it's perpetually shrouded in thick, yellowish clouds of sulfuric acid that trap heat, causing a runaway greenhouse effect. It's the hottest planet in our solar system, even though Mercury is closer to the Sun. Surface temperatures on Venus are about 475 degrees Celsius hot enough to melt lead. The atmospheric pressure is 90 times that on the earth which would crush anything like a tin can. And colonizing Venus won't give the asteroid mining advantage, would it?

Figure 2: Mars with icecaps

When compared to the Moon, Mars is rich in carbon, nitrogen, hydrogen, and oxygen, all in biologically readily accessible forms such as carbon dioxide gas, nitrogen gas, frozen water in form of ice, and permafrost. Carbon, nitrogen, and hydrogen are only present on the Moon in parts per million quantities, much like gold in seawater. Oxygen is abundant on the Moon, but only in tightly bound oxides such as silicon dioxide (SiO2), ferrous oxide (Fe2O3), magnesium oxide (MgO), and aluminum oxide (Al2O3), which require very high energy processes to reduce. Current knowledge indicates that if Mars were smooth and all its ice and permafrost melted into liquid water, the entire planet would be covered with an ocean over 100 meters deep. This contrasts strongly with the Moon, which is so dry that if concrete were found there, Lunar colonists would mine it to get the water out. Thus, if plants could be grown in greenhouses on the Moon (an unlikely proposition, as we've seen) most of their biomass material would have to be imported. But the soil on Mars can be treated by a complicated process to be able to support plant growth. The Moon is also deficient in about half the metals of interest to industrial society (copper, for example), as well as many other elements of interest such as sulfur and phosphorus. Mars has every required element in abundance. Moreover, on Mars, as on Earth, hydrologic and volcanic processes have occurred that are likely to have consolidated various elements into local concentrations of high-grade mineral ore. Indeed, the geologic history of Mars has been compared to that of Africa, with very optimistic inferences as to its mineral wealth implied as a corollary. In contrast, the Moon has had virtually no history of water or volcanic action, with the result that it is composed of trash rocks with very little differentiation into ores.

Titan's atmosphere is similar to Earth's both in the predominance of nitrogen gas and in surface pressure, which is about 1.5 bars, or 50 percent higher than sea-level pressure on Earth. Titan's atmosphere is much colder, however, having a temperature at the surface of 94 K (-179 degree Celsius), and it contains no free oxygen. A troposphere analogous to Earth's extends from Titan's surface to an altitude of 42 km (26 miles), where a minimum temperature of 71 K (-202 degree Celsius) is reached. Clouds of nitrogen are not present, apparently because temperatures are always above the condensation point of nitrogen. But Titan is out of the question because it is too far from the earth and would take 14 years, whereas it takes only 6 months to Mars.

The First steps

An experiment was conducted to test the effects on the crew when they will live on Mars completely separated from the earth. Biosphere 2 (figure 3a), is an American Earth system science research facility located in Oracle, Arizona. They constructed the largest closed self-sustainable ecological system spread across 3.14 acres, between 1987 and 1991, to test the technologies we would use to colonize Mars. The idea was to have 8 people live inside the biosphere for 2 years completely cut off from the outside world. They would have to grow their food, recycle their waste, and get oxygen from the rainforest they grew inside the compound. Biosphere 2 received a whole lot of media attention and 8 people signed up for this test (figure 3b). The second mission started on March 6th, 1994, with a run of 10 months, and 7 people signed up this time.

(a) Bioshpere 2 (b) Inside Biosphere 2

Then SpaceX entered the race. Elon Musk first presented his goal of enabling Mars colonization in 2001. Between the 2000s and early 2010s, SpaceX made many vehicle concepts for delivering payloads and crews to Mars, including space tugs, heavy lift launch vehicles, and Red Dragon capsules. The company's current Mars plan was first formally proposed at the 2016 International Astronautical Congress alongside a fully reusable launch vehicle, the Interplanetary Transport System. Since then, the launch vehicle proposal was altered and renamed to "Starship" and has been in development since (figure 4). The company has given many estimates of the dates of the first human landing on Mars. And now many big new players, private and government agencies, have entered the race.

Figure 4: Starship in testing

Okay, Mars is a good planet to build a colony on and is also close to the earth then, let's go to it and build a colony there. Wait, this was one side of the coin, let's take a look at the other.

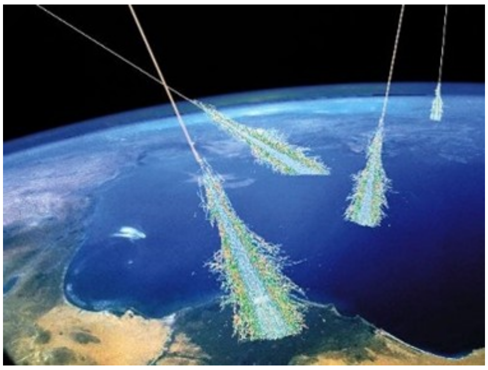
The Dark Side

It is easy to say to build colonies on other planets and declare us as interplanetary species. But many difficulties need to be overcome and lots of impossible tasks need to be successfully pulled off. Mars is very harsh. And not only that, living with the same people for years could lead to some dire consequences. Remember that Biosphere 2 eco-system, the project ran into many problems.

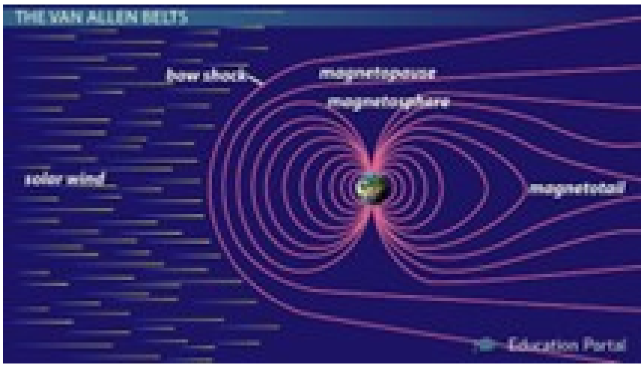
After only 12 days, one of the crew members accidentally cut her hand off while processing rice, and the medical team had to get in and treat her, already breaking the rules. There were several incidents like this and breaking even more rules. And by the time the run was over, the crew was split into two groups and refused to even talk to the other group and this whole project turned out to be a disaster. Even if we consider that the people will stay sane the whole time, there are multiple problems on Mars itself. Let's have a look at them.

0.1 Radiation

Mother Earth protects us, nurtures us, and keeps us safe. We are spoiled and expect the same conditions in outer space and on other planets, but in reality, it is a nightmare. The protective magnetic sphere of the earth keeps life safe from very harsh radiation, cosmic rays (figure 5a), and high-energy particles, without it we would be burnt toast with a high dose of cancer. There are only 24 people who left the magnetosphere (figure 5b) during the Apollo missions. All astronauts reported multiple cardiovascular problems and they were out there for only 2 weeks. So, imagine what will happen when they go to Mars which has a journey of 6 months, double that for a return trip, plus the time spent on Mars which has no magnetosphere and a very thin atmosphere.

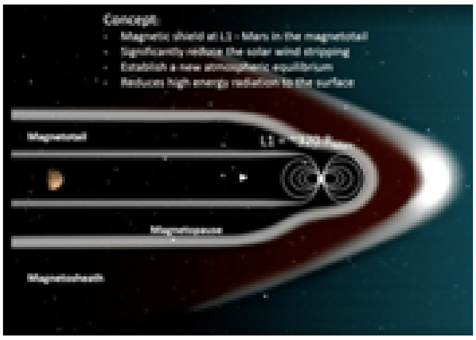


(a) Cosmic-rays scattered by atmosphere

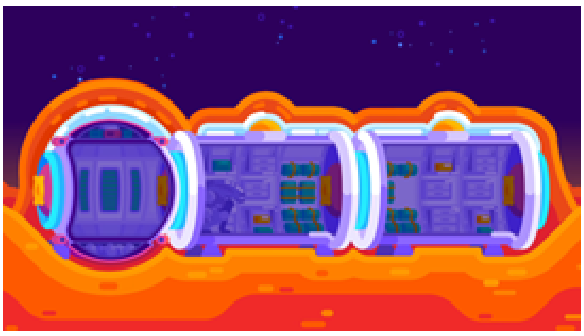


(b) Magnetosphere of Earth

There are some solutions to this problem, one of which is to place a satellite between Mars and the Sun at the L1 Lagrange point, creating a Tesla tube that would protect it from radiation (figure 6a). But cosmic rays would still be a problem. Another solution is to cover the modules with a layer of frozen CO2 which can be extracted from the Martian atmosphere and then cover it with Martian soil (figure 6b). Another simple solution is to set up bases in underground tunnels.



(a) Proposed Tesla tube



(b) Mars base covered with Martian soil

0.2 The launch window

The launch window for any mission to Mars comes approximately every 26 months. The type of trajectory the spacecraft will follow to Mars is known as the 'Hohmann Transfer' (figure 7) which will take another 6-7 months journey. Suppose an emergency occurs on Mars and we need to send help, it won't be possible as the journey duration is long plus the waiting time for the launch window. Sure, there will be some medical equipment available on Mars which hopefully would be sent on cargo missions. But many different problems could arise (even those which we can't imagine) and would need assistance from the earth and we could only watch.

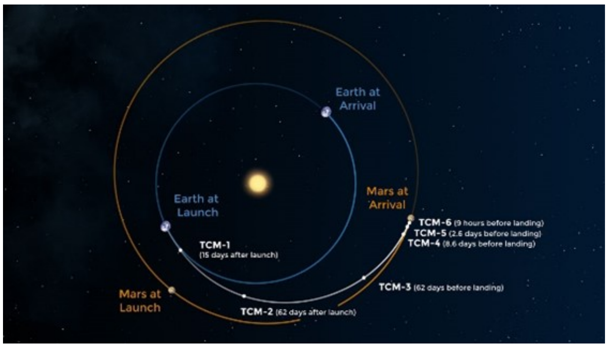


Figure 7: Hohmann Transfer

During their long travel, the crew will face Cardiovascular problems which can be suppressed (to an extent) by exercising. Even though the astronauts on the International Space Station exercise for many hours, they still face the problem. The risk of cardiovascular problems of an astronaut is more than that of a normal human given that healthier people are selected as astronauts.

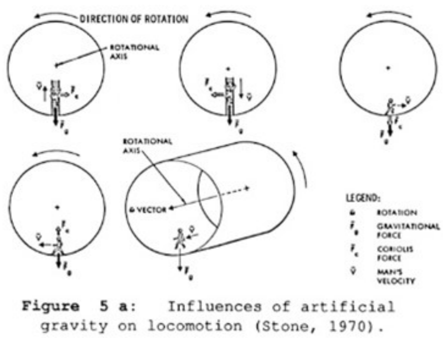
0.3 Gravity

Mars is smaller than the earth and has 38% of the gravity on the earth. This means a guy weighing 120 kg would only weigh about 46 kg, which seems pretty exciting. But wait, being in low gravity for long periods leads to very serious problems in the human body like bone loss, atrophied muscles, and cardiovascular issues. We have no idea how low gravity would affect the human body for long periods, but we have some idea of how zero gravity (some call it microgravity) would affect it. Astronaut Scott Kelly and cosmonaut Mikhail Kornienko spent 340 days in space, with scientists performing medical experiments. Astronauts even struggle to walk when they land on earth (figure 8). Then imagine what would happen to the astronauts when they were in zero gravity for 6 months and then they would have to relearn to walk in 0.38G on Mars. On earth, there are people to help them but out there they only have to help themselves. That would be a really difficult challenge to overcome.

Figure 8: An Astronaut struggling to walk

Well, there are some solutions to get gravity on rockets and Mars. One of which is to use a 1G rocket. This rocket accelerates at 1G for the first half of the trip and then flips around to retard at 1G for the second half of the trip. This way we will get a constant gravity of 1G all the time. But there is one catch, ‘Fuel’. Combustion engines cannot be used as they burn out in a couple of minutes, there are other engines like ion and nuclear but the size required for that kind of acceleration and retardation would be very large, and the amount of fuel required for that would also be high. However, we can create artificial gravity in the form of ‘Rotational Gravity’ (figure 9a). Using large spinning cylinders will give the effect of gravity (figure 9b) but this gravity is not the same as the gravity on the earth. While standing you may not feel any different, but as soon as you turn your head the fluids in your ears will start flowing differently. Best case, one will lose their balance, worst case, their consciousness. These effects will get worse as the size of the container is reduced. And rotating containers will unnecessarily use up electricity which will be hard to generate on Mars. So currently, there is no efficient way we can create artificial gravity unless a breakthrough happens, and gravitons are found. Major research is going on at the CERN particle accelerator to find gravitons. These particles could be manipulated for our use. We could then just turn on and off gravity, just like we turn electrons into photons with just a click of a button.

(a) A Space settlement with rotational gravity



(b) Rotational gravity

0.4 Power generation

Generating electricity on Mars will be a huge challenge. Geothermal energy cannot be used as the core of Mars is much too cold. Wind power is also not efficient as there is hardly any atmosphere. Because of its distance from the Sun, solar power is only 40% effective (figure 10). Even if we set up a huge field for solar power generation, their frequent cleaning will be a huge problem because of the fine dust found on Mars (more on that in a minute). The only effective way to generate energy is the use of atomic energy. But there are no accessible sources of radioactive material on Mars, so the fuel along with the reactor would have to be transported from the earth. This will meet the energy requirements of the colony for the first couple of years.

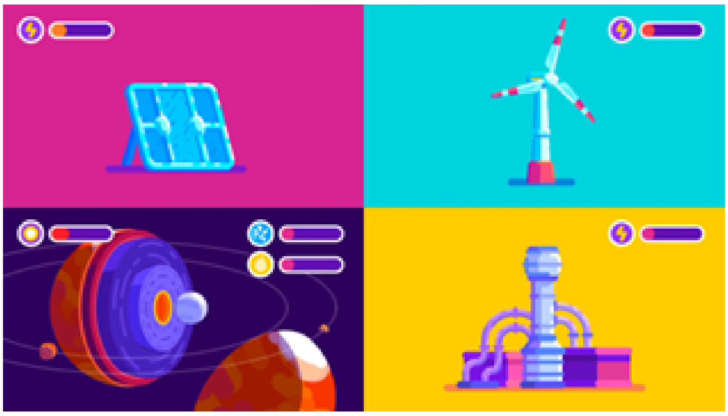


Figure 10: Power generation on Mars

0.5 Martian dust and soil

Martian soil is no good and to add a cherry on top, the dust is finer than that on the earth. There are frequent massive dust storms that last about 7-10 days (figure 11a). This dust is similar to the dust on the moon. During Apollo missions only after a few days, the dust got everywhere, in the suits, the equipment, and even in the capsule. The astronauts looked like they had just returned from mining coal (figure 11b). The same problem would occur on Mars. This dust caused major damage to the Curiosity rover's wheels. This dust would get into the modules, and the gears in the pieces of equipment could wear them out earlier than expected. And because it is very dry, it is electrostatically charged and will stick to everything, and cleaning won't even help.

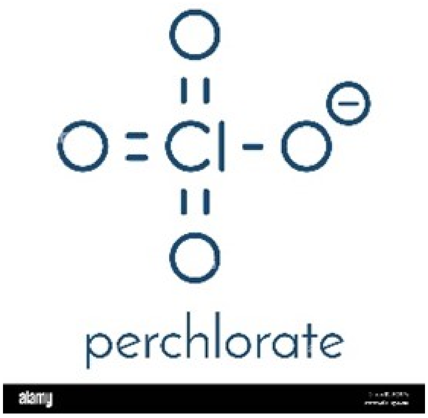
Water won't be a problem if a settlement is located near the icecaps. However, growing plants is a challenge. The Martian soil is alkaline with a pH of 8-9 and also lacks the vital nitrogen compounds that plants need to grow. In 2008, the Mars Phoenix lander found large amounts of perchlorates in the soil with concentrations between 0.5%-1%. Perchlorates ($ClO4-$) (figure 12a) are salt compounds that

(a) Dust storm on Mars

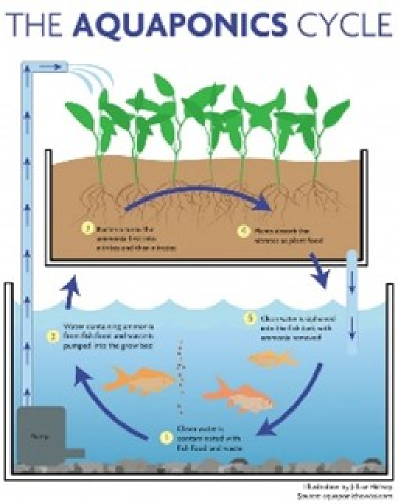
(b) Astronaut covered in Moon dust

are often used in rocket propellants and are very toxic to humans. They interrupt the thyroid gland and prevent the body from absorbing iodine which leads to Aplastic Anemia. In this, the body is not able to produce enough RBCs. One can also get Agranulocytosis, in which the body is not able to produce WBCs. Without WBCs the crew would be very vulnerable to anything, even to a minor infection. The effects of long-term exposure to perchlorates are still unclear.

So, if they want to grow plants on Mars (which they would have to), soil from the earth has to be sent with the crew or they would have to process it first, which might be very energy intensive and difficult. But still, with all the processing, some minor exposure is inevitable. Aquaponics (figure 12b) is a good solution for the cultivation of crops and fish. This would provide a larger platter for the crew and will fulfill the nutritional requirements.



(a) Chemical structure of perchlorate ion



(b) Aquaponics

0.6 Contamination

In Drake's equation, fl is the one about planets that have life on them and so far, we only know about one and that's earth. That is why finding microbial life on other planets would be one of the most profound discoveries in human history. If life can form twice in one solar system, the chances of intelligent life developing in the universe go up drastically.

The problem with going to Mars is that humans are not the only ones to go there. The crew would be carrying millions of microbes with them. The second we landed on Mars, we contaminated it. Some even believe that we have already contaminated it. There have been 14 probes sent to Mars, despite sanitation procedures and assembling the probe in clean rooms, it's impossible to know whether it was carrying any microbes or not. We don't trust machines to verify any microbial life on Mars, humans would have to do it themselves. This is a catch-22 situation, to verify life on Mars we would have to go there but, if we go there, it is already contaminated.
But the species found on Mars would probably be different from what is found on the earth. We could validate the results this way.

Conclusion

Sending humans to Mars and setting up a colony there, where the crew would have bone loss and cardiovascular problems due to low gravity. Also, the crew would have conditions like Aplastic Anemia and Agranulocytosis, which will lead to a really weak immune system, and various types of cancers due to radiation is a really good idea. It's not. However, these problems can be solved. Some are as simple as living underground to counter radiation and some are extremely complicated like processing soil to reduce its perchlorate content.
Indeed, there are indeed many challenges to face. But there is one x-factor, 'We are Humans', and humans are ambitious. Humans are a race of explorers and pioneers, and we are brave, it's in our DNA. Where we would be if our ancestors didn't come down from the trees, or explored the seven seas and spread across the globe? We have overcome many challenges in the past. In the past, going into space seemed sci-fi and impossible in real life but, we did it. We faced many challenges, but we still reached the moon. Similarly, we would also overcome every challenge which comes in our path and reach Mars and set up a colony. Now, we have almost all the data, a planned timeline, a plan for the journey, the problems which would arise, and possible solutions to these problems. Would you be one of the first to go to Mars?