Mars: Economic Analysis of Constructing Sustainable Open-Air Human Settlements in The Martian Environment

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MARS: ECONOMIC ANALYSIS OF CONSTRUCTING SUSTAINABLE OPEN-AIR HUMAN SETTLEMENTS IN THE MARTIAN ENVIRONMENT

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ABSTRACT

With a high surface radiation, very low and fluctuating temperature and a windy but thin atmosphere, Mars seems an inhospitable place. The dangers on the Martian surface entail that humans stay within indoors habitats on Mars. But it may be possible to build open air settlements on Mars where a direct connection to the Martian atmosphere is feasible. In such a scenario, humans may be able to inhabit Mars with minimal external protection like pressurized suits. For this to happen, humans need to be in atmospheric conditions similar to that on Earth.

To achieve these results we need to excavate deep into the Martian crust to depths where air pressures will be sufficient to allow humans to survive without pressurized suits. The paper discusses about the various aspects and economic analysis of such an exercise. The hurdles for implementing this plan are also analyzed. The paper concludes by summarizing the feasibility, benefits and difficulties in undertaking such an activity.

INTRODUCTION

Present conditions on Mars are deemed hostile for human life. One of the main reasons is that Mars has a very thin atmosphere. The highest atmospheric density on Mars is equal to that found 35 km above Earth's surface (0.6 kPa). This is way below the Armstrong limit [1] At such low pressures, body fluids will instantly boil off. There is a very real danger of explosive decompression, if a human body is exposed to Martian conditions without any protection.

I envisage a scenario where humans may be able to inhabit Mars with minimal external protection like pressurized suits. For this to happen, humans need to be in atmospheric conditions similar to that on Earth.

It is the law of physics that on earth (or any planet with an atmosphere), travelling every few meters into the crust will increase the atmospheric pressure by a certain amount. Similarly, we will face increase in atmospheric pressure, the deeper we travel into Mars's crust.

The idea is to drill a vertical shaft 20 km deep and 15 meters wide. Once we reach the base (20 km deep), Horizontal drilling will be undertaken, excavating a 1 sq km by 30 meters volume of space, creating living areas for human habitation.

Empirical calculations show that at such depths, the atmospheric pressure will be equivalent to that at the top of Mount Everest (on Earth). The open atmosphere of Mars will be stably connected to the higher atmospheric pressure (due to Gravity) in the underground 'Cavern' that humans will be excavating inside Mars.

With suitable acclimatization procedures, Astronauts may be able to survive without pressurized suits or heavy protection, though oxygen masks will be needed to supply breathable air.
Smaller units within the settlements can be constructed which can provide a fully earth like atmospheric conditions.

With increasing depth, temperatures will also rise, probably leading to a tolerable level where human skin can be exposed to Martian atmosphere.

If drilling takes place at the centre of the Hellas Planitia basin floor (the lowest point on Mars) [2], then we need to drill only for around 16.5 Kilometers to achieve the pressure equivalent to that on the summit of Mount Everest.

CALCULATIONS

Martian rock density = 3.7 g/cm3
20 km deep 15 m diameter hole = 3.53×10^6 m^3 of soil/rock.
D = M/V
M = V x D
= $3.53 \times 10^6 \times 3.7$ tons.
= 13.061 million tons need to be excavated
= 14 million tons (approx)
1 sq km x 30 m
= 3×10^7 m^3 of soil and rock.
= 111 million tons
Total = 111 + 14 = 125 million tons of rock.

Since gravity is only 38% that of Earth, corresponding weight of the debris and excavated material will be only 47.5 million tons of rock/ soil.

<u>The reasons why such a habitat is required are manifold</u>:-

(1) The psychological cost of staying for prolonged periods in a closed space on the human mind is very high [3].
Studies have shown that living in limited space conditions for long periods of time may impact the personality of astronauts. Changes in the very nature of a person's psychology may be dangerous to the space missions or future space societies that develop. After long and continuous space journeys, open spaces will provide a home like atmosphere.

(2) Human habitats on Mars will be mostly indoors [4]. For human settlements to expand freely with minimal hindrance, we need to provide open atmospheric conditions similar to that on Earth. This will allow increased mobility, allowing better productivity and increased comfort levels to astronauts.

(3) Astronauts will be able to lead as normal a life as possible without the fear of explosive decompression.

(4) A space dome will be exposed to the vagaries of Martian weather. Any meteorite striking Mars' atmosphere has higher chance of reaching the surface due to the thin atmosphere. Such impacts are dangerous to space domes as they may cause decompression of a large volume of space or within the space dome in very short time intervals.

(5)Mars has no global magnetosphere like the Earth. And due to a thin atmosphere, significant amounts of ionizing radiations reach the Martian surface. Cosmic and solar radiation from outer space will be harmful if human settlements are on the Martian surface. Deep underground, humans will be shielded from deadly ultraviolet and cosmic radiation. The interiors of the caverns will be shielded from meteoroids, UV radiation, high energy particles and solar flares that assail the Martian surface [5].

(6)Temperature variations are more on surface settlements. As a consequence, we have to expend more energy to maintain a constant temperature. Deep underground, we can maintain a constant temperature of a large volume of space at lesser energy costs due to insulating nature of the Martian underground.

(7)By having co-equal pressure (i.e. pressure in Earth like conditions) it is possible to set up huge factories which will produce a variety of products from Martian resources. This will enable us to industrialize the Martian society.

(8)Underground settlements provide a relatively sterile environment and protection from dust. This will enable humans to lead a fair standard of life with less morbidity as dusty environments are known to increase morbidity [6].

(9)Mars can have a series of such interconnected 'Caverns' which will enable to travel freely under the Martian Surface to different locations on the planet. A future Martian society can thus develop freely in such interconnected 'Caverns'.

(10) With a system of airlocks in place, it will be possible to fill the whole cavern with oxygen and nitrogen and create an Earth-Like atmosphere. In such cases, even a failure of the airlocks will not be very dangerous as explosive decompression can be easily avoided (due to co-equal pressure with summit of Mt.Everest).

(11) As a large amount of Martian Rock, soil and debris will be excavated, it provides a great opportunity to 'mine' the excavated debris for ores and other useful materials. This will save the effort, time and energy to specifically undertake a mining-only operation on Mars.

ECONOMICS OF CONSTRUCTING AN OPEN AIR SETTLEMENT:

Before this project is undertaken, the Martian Colony should have a fairly large economy to support this project. We can take the channel tunnel (as it was a Large Excavation Project) as a model on which to base our economic evaluation.

The channel tunnel costed around $ 5 Billion (1985) to construct. The combined economy (GDP) of France and United Kingdom was around $1 trillion in 1985 (World Bank). Therefore the resources needed will be around 0.5% of the GDP of the Economy of the entity that constructs the tunnel. If the excavation of vertical shaft is taken as a project equivalent to the channel tunnel, then excavating the Cavern will be equivalent to around 8 times the project to drill a vertical shaft (amount to matter excavated for cavern will be about 8 times that of the Vertical shaft-refer calculation).

Therefore, the entire project (shaft plus Cavern) will consist of 9 units of excavation (1 unit for Vertical Shaft and 8 Units for Cavern). Therefore the total project of constructing sustainable open-air human settlement on Mars will be about 0.5/9=0.0556% of the GDP of the Martian Economy at that time.

This means that if the projected cost of the endeavor is about $50 Billion (in future), then the Economy of Martian Colony will have to equivalent to (approx.) 90,000 Billion, i.e. $ 90 Trillion to support the project. The GDP of Earth today (2013 figures) is $75.59 Trillion [7]. Mars will be populated with humans who will have higher skill and training (compared to average earth population) because the conditions on Mars demand a high-value human resource. Because of such high-value human resource and possibly high-value equipment, it will take Mars very less time to develop a $ 75 Trillion Economy. Still the time may be in decades if not in centuries.

Such an endeavor will therefore be sustainable, only if we have a large Martian Economy (as large enough as Earth's) that can support this activity. Therefore, a project of this scale may be feasible only in the medium to long term.

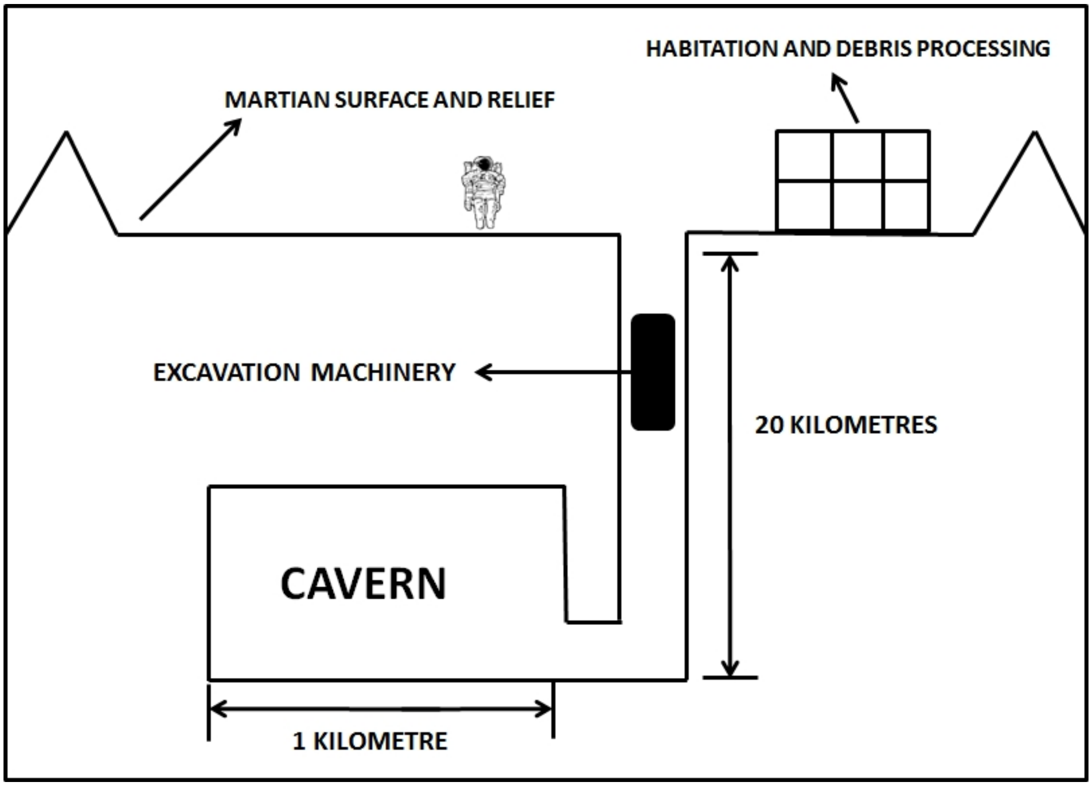

IMAGE NOT TO SCALE

HURDLES FOR IMPLEMENTATION

1. As the infrastructure needed is very heavy and investment required is large, early Martian settlements cannot afford to undertake construction of the cavern.

2. The effect of high concentration of Martian carbon di oxide on the skin or direct absorption from skin and related effects have to be studied.

3. We need more knowledge of Martian geology before we can undertake such a project.

4. Those undertaking this project must be ready for human, equipment and other failures including many safety issues.

5. It will probably take a long time to drill a 20 km vertical shaft (probably more than 1 Martian year) and almost 5 times longer to excavate a 1 km by 30 m cavern if present day methods deployed on earth are used. Using advanced methods like nanotechnology (using automated nanobots for excavation) and other techniques may complete the work faster and in a cheaper way.

6. The cost involved may be very high and most probably prohibitive.

7. We need to also consider the fact that reduced Martian Gravity will have different effects on atmospheric pressure underground. Its variation with depth will not be the same as that on Earth. This issue needs to be factored in. It may be that humans might need to drill and go deeper than 20 Kms to excavate the 'Cavern'.

CONCLUSION

With high surface radiation, very low and fluctuating temperature and a windy but thin atmosphere, Mars seems an inhospitable place. The dangers on the Martian surface will entail that human beings stay in indoor habitats on Mars. Always staying indoors on the surface of mars comes with its own disadvantages. But it is possible to build open air settlements on Mars where a direct connection to Martian atmosphere is possible.

Most of the benefits of such an exercise accrue from the Underground nature of the settlement. Many other factors and variables need to be evaluated, analyzed and studied. With the dangers of explosive decompression, meteorite strikes, cosmic rays, inclement Martian weather and wildly fluctuating temperatures on the Martian surface, such a settlement will be a necessity in the long-term if not in the early days of Human Mars exploration. Though the cost and efforts seem prohibitive at present, it may be feasible in a scenario where Mars will have a developed Economy in future.

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