ON COLONIZING MARS

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Summary. *This document analyses why and how can be colonized Mars by implementing a series of technical state-of-the-art leaps, all of them focused in reducing the cost for a ticket ride to Mars. It is also evaluated the feasibility of a series of possibilites of colonization.*

1 INTRODUCTION

1.1 How?

For many years NASA and several private companies have issued they interest on going to Mars. SpaceX is characterized for a rapid and cheap manufacture of rockets, and by having ludicrously ambitious goals. Born a decade ago, currently it leads space industry and was founded to ultimately help to build a 'self sustaining civilization on Mars'. A new system design, headed by a humongous rocket, encoded as BFR (Big Falcon Rocket), is due to be ready on less than a decade and will be evaluated in detail. This system implements new technologies, such as full reusability, In-Situ Resource Utilization (ISRU), refueling in orbit, high mass and volume capabilities, and a light, powerful and multiple-purpose rocket.

The technologies applied to BFR are detailed and determined to be more budget-focused than physically required per se. These provide a 10000% reduction of the cost it would require an Apollo-type mission, a necessity to match offer and demand of an average person buying a trip to Mars, but also compulsory to enable investment to be sufficient.

1.2 Why?

Statistical calculations [1] determine that a backup planet is necessary for a likely case of global annihilation.

Table 1: Estimated probability for human extinction before year 2100

Overall probability	**19%**
Molecular nanotechnology weapons	5%
Superintelligent AI	5%
All wars (including civil wars)	4%
Engineered pandemic	2%
Nuclear wars	1%
Nanotechnology accident	0.5%
Natural pandemic	0.05%
Nuclear terrorism	0.03%

A more profound reason to colonize Mars is providing humankind with an inspirational project that gets people together and diminish differences between people.

2 TECNICAL REQUIREMENTS

2.1 Full reusability

Instead of increasing production of a product, the analogy of economies of scale is to increase the number of times a rocket is used instead of being expendable. This works for the commercial airplanes which would be unaffordable if only used once. Currently, SpaceX customer's are satellites communication firms, NASA, and U.S.Airforce, which benefit from Falcon 9 rocket, the cheapest rocket in market, even without taken into consideration full reusability. Each rocket costs to customer around 62 million dollars and production and operation costs are about 40 million dollars, so the margin is around 18 million dollars. However, SpaceX is capable to land the booster, which is 80% of the total cost of the rocket, and reuse it, up to ten times. Given that the reusability cost of the booster is estimated to be 'substantially less than half' [2] of a new rocket, the margin for a second reuse would be 38 million dollars, double. Reuse is limited to technical restrictions related to risk assumption and cost of refurbishment tend to increase within each use, but there is plenty of margin to reduce cost of refurbishment to almost just the cost of the fuel.

In other words, being conservative and considering refurbishment cost remains the same in the future, the cost for the launches for a Falcon 9 rocket follows:

$$C/c = (n-1) \times 0,6 + 1 \tag{1}$$

Being C=total cost for n launches, c= cost for a new rocket, and n the number of launches.

The BFR is designed to be refurbished completely (upper stage and lower stage or booster). Expertise from Falcon 9 will be applied to obtain an even more resilient, but

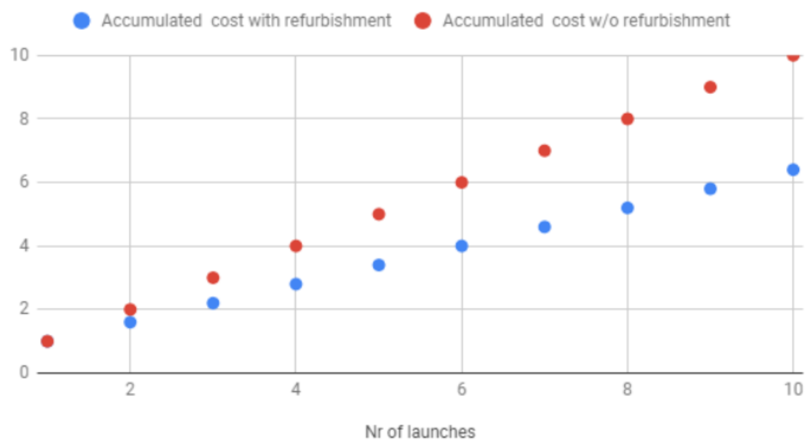

Figure 1: Relative accumulated cost of Falcon 9 launches

on the other hand, more expensive rocket. To counter this, it is expected to be launch 100 times.

2.2 Refueling in orbit

Refueling is imperative to achieve enough total payload mass for each trip to Mars. For a BFR in orbit without refueling, a BFR would merely achieve Mars with the cargo bay empty. But with a full fuel tank, 150 tons of cargo could reach the surface of Mars. This is not only a necessity because an expedition would require several supplies, but, again, sending one ton of cargo instead of 150 tons can be interpreted as requiring two magnitude orders less launches to carry same amount of to mass to Mars, reducing overall cost and opening the market for potential investors -mainly governments- or rich people.

2.3 In-Situ Resource Utilization

In order not to carry with us the fuel necessary to return to earth, our expeditions should be capable of producing it there. The unlimited amount of water (5 million km^3 of water ice) and 25 trillion metric tons of H_2O on Mars' atmosphere leds to use them to produce methane with a Sabatier reaction (2). Of course, the energy to produce this reaction must be supplied, using nuclear reactors or solar panels.

$$2H_2O + CO_2 \rightarrow 2O_2 + CH_4 \tag{2}$$

Other common rocket propellants had been revised by SpaceX as possible alternatives, but neither of them where as suitable as methane. The reason is mainly the resources that Mars can naturally offer.

Table 2: Mars propellant production feasibility

Kerosene	Hydrogen	Methane
VERY BAD	JUST OK	GOOD

2.4 Multi-purpose rocket

In order to be capable of selling more launches with the same rocket there must also be a market demand to enable it. A market demand can be created if cutting-edge technology and new ideas open new possibilities. Such is the case of the earth-to-earth orbital trips proposal of SpaceX. BFR enables to go to *any part of the world in less than an hour*[4]. The customers can be not just private companies, or governments, but wealthy people.

3 TERRAFORMING

Terraforming Mars would involve three linked changes: building up the atmosphere, building up the magnetosphere, and raising the temperature.

The atmosphere of Mars is thin and has a pressure a hundred times lower than earth's pressure. Because its atmosphere consists mainly of CO2, once Mars begins to heat, the CO2 should help keep thermal energy near the surface. Moreover, as it heats, more CO2 should enter the atmosphere from the frozen reserves on the poles, enhancing a greenhouse effect which retrofits itself. Importing ammonia from minor planets orbiting in the outer Solar System would be an alternative solution.

Since the planet's creation, it is believed that the lack of techtonics did not provide Mars of a powerful enough magnetic field, so through the eons, the cosmic and solar rays removed the atmosphere progressively. A global magnetic field would probably be necessary to avoid this. Main theorized solutions would be building a system of refrigerated latitudinal superconducting rings or deploying a magnetic dipole shield at the Mars L1 Lagrange point, therefore creating an artificial magnetosphere. This could be achieved by a magnet with a strength of one or two Tesla.[5]

4 CONCLUSIONS

It is concluded that the reasons to promote Mars' colonization are ranged from practical to close to the spiritual, and not only possible, but necessary. Seems quite feasible to arrive to its surface and build a base in the near future. Nevertheless, the possibility to terraform it seems more science-fiction with the technology available. Possibly, the pace of development will yield to technologies we do not even imagine. For the moment we can only theorise methods and dream about it.

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