The Case for Colonizing Mars

by Robert Zubrin

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Mars Is The New World

Among extraterrestrial bodies in our solar system, Mars is singular in that it possesses all the raw materials required to support not only life, but a new branch of human civilization. This uniqueness is illustrated most clearly if we contrast Mars with the Earth's Moon, the most frequently cited alternative location for extraterrestrial human colonization.

In contrast 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, and water 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 (SiO_2), ferrous oxide (Fe_2O_3), magnesium oxide (MgO), and aluminum oxide (Al_2O_3), 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.

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 basically composed of trash rocks with very little differentiation into ores that represent useful concentrations of anything interesting.

You can generate power on either the Moon or Mars with solar panels, and here the advantages of the Moon's clearer skies and closer proximity to the Sun than Mars roughly balances the disadvantage of large energy storage requirements created by the Moon's 28-day light-dark cycle. But if you wish to manufacture solar panels, so as to create a self-expanding power base, Mars holds an enormous advantage, as only Mars possesses the large supplies of carbon and hydrogen needed to produce the pure silicon required for producing photovoltaic panels and other electronics. In addition, Mars has the potential for wind-generated power while the Moon clearly does not. But both solar and wind offer relatively modest power potential — tens or at most hundreds of kilowatts here or there. To create a vibrant civilization you need a richer power base, and this Mars has both in the short and medium term in the form of its geothermal power resources, which offer potential for large numbers of locally created electricity generating stations in the 10 MW (10,000 kilowatt) class. In the long-term, Mars will enjoy a power-rich economy based upon exploitation of its large domestic resources of deuterium fuel for fusion reactors. Deuterium is five times more common on Mars than it is on Earth, and tens of thousands of times more common on Mars than on the Moon.

But the biggest problem with the Moon, as with all other airless planetary bodies and proposed artificial free-space colonies, is that sunlight is not available in a form useful for growing crops. A single acre of plants on Earth requires four megawatts of sunlight power, a square kilometer needs 1,000 MW. The entire world put together does not produce enough electrical power to illuminate the farms of the state of Rhode Island, that agricultural giant. Growing crops with electrically generated light is just economically hopeless. But you can't use natural sunlight on the Moon or any other airless body in space unless you put walls on the greenhouse thick enough to shield out solar flares, a requirement that enormously increases the expense of creating cropland. Even if you did that, it wouldn't do you any good on the Moon, because plants won't grow in a light/dark cycle lasting 28 days.

But on Mars there is an atmosphere thick enough to protect crops grown on the surface from solar flare. Therefore, thin-walled inflatable plastic greenhouses protected by unpressurized UV-resistant hard-plastic shield domes can be used to rapidly create cropland on the surface. Even without the problems of solar flares and month-long diurnal cycle, such simple greenhouses would be impractical on the Moon as they would create unbearably high temperatures. On Mars, in contrast, the strong greenhouse effect created by such domes would be precisely what is necessary to produce a temperate climate inside. Such domes up to 50 meters in diameter are light enough to be transported from Earth initially, and later on they can be manufactured on Mars out of indigenous materials. Because all the resources to make plastics exist on Mars, networks of such 50- to 100-meter domes couldbe rapidly manufactured and deployed, opening up large areas of the surface to both shirtsleeve human habitation and agriculture. That's just the beginning, because it will eventually be possible for humans to substantially thicken Mars' atmosphere by forcing the regolith to outgas its contents through a deliberate program of artificially induced global warming. Once that has been accomplished, the habitation domes could be virtually any size, as they would not have to sustain a pressure differential between their interior and exterior. In fact, once that has been done, it will be possible to raise specially bred crops outside the domes.

The point to be made is that unlike colonists on any known extraterrestrial body, Martian colonists will be able to live on the surface, not in tunnels, and move about freely and grow crops in the light of day. Mars is a place where humans can live and multiply to large numbers, supporting themselves with products of every description made out of indigenous materials. Mars is thus a place where an actual civilization, not just a mining or scientific outpost, can be developed. And significantly for interplanetary commerce, Mars and Earth are the only two locations in the solar system where humans will be able to grow crops for export.

Interplanetary Commerce

Mars is the best target for colonization in the solar system because it has by far the greatest potential for self-sufficiency. Nevertheless, even with optimistic extrapolation of robotic manufacturing techniques, Mars will not have the division of labor required to make it fully self-sufficient until its population numbers in the millions. Thus, for decades and perhaps longer, it will be necessary, and forever desirable, for Mars to be able to import specialized manufactured goods from Earth. These goods can be fairly limited in mass, as only small portions (by weight) of even very high-tech goods are actually complex. Nevertheless, these smaller sophisticated items will have to be paid for, and the high costs of Earth-launch and interplanetary transport will greatly increase their price. What can Mars possibly export back to Earth in return?

It is this question that has caused many to incorrectly deem Mars colonization intractable, or at least inferior in prospect to the Moon. For example, much has been made of the fact that the Moon has indigenous supplies of helium-3, an isotope not found on Earth and which could be of considerable value as a fuel for second generation thermonuclear fusion reactors. Mars has no known helium-3 resources. On the other hand, because of its complex geologic history, Mars may have concentrated mineral ores, with much greater concentrations of precious metal ores readily available than is currently the case on Earth — because the terrestrial ores have been heavily scavenged by humans for the past 5,000 years. If concentrated supplies of metals of equal or greater value than silver (such as germanium, hafnium, lanthanum, cerium, rhenium, samarium, gallium, gadolinium, gold, palladium, iridium, rubidium, platinum, rhodium, europium, and a host of others) were available on Mars, they could potentially be transported back to Earth for a substantial profit. Reusable Mars-surface based single-stage-to-orbit vehicles would haul cargoes to Mars orbit for transportation to Earth via either cheap expendable chemical stages manufactured on Mars or reusable cycling solar or magnetic sail-powered interplanetary spacecraft. The existence of such Martian precious metal ores, however, is still hypothetical.

But there is one commercial resource that is known to exist ubiquitously on Mars in large amount — deuterium. Deuterium, the heavy isotope of hydrogen, occurs as 166 out of every million hydrogen atoms on Earth, but comprises 833 out of every million hydrogen atoms on Mars. Deuterium is the key fuel not only for both first and second generation fusion reactors, but it is also an essential material needed by the nuclear power industry today. Even with cheap power, deuterium is very expensive; its current market value on Earth is about $10,000 per kilogram, roughly fifty times as valuable as silver or 70% as valuable as gold. This is in today's pre-fusion economy. Once fusion reactors go into widespread use deuterium prices will increase. All the in-situ chemical processes required to produce the fuel, oxygen, and plastics necessary to run a Mars settlement require water electrolysis as an intermediate step. As a by product of these operations, millions, perhaps billions, of dollars worth of deuterium will be produced.

Ideas may be another possible export for Martian colonists. Just as the labor shortage prevalent in colonial and nineteenth century America drove the creation of "Yankee ingenuity's" flood of inventions, so the conditions of extreme labor shortage combined with a technological culture that shuns impractical legislative constraints against innovation will tend to drive Martian ingenuity to produce wave after wave of invention in energy production, automation and robotics, biotechnology, and other areas. These inventions, licensed on Earth, could finance Mars even as they revolutionize and advance terrestrial living standards as forcefully as nineteenth century American invention changed Europe and ultimately the rest of the world as well.

Inventions produced as a matter of necessity by a practical intellectual culture stressed by frontier conditions can make Mars rich, but invention and direct export to Earth are not the only ways that Martians will be able to make a fortune. The other route is via trade to the asteroid belt, the band of small, mineral-rich bodies lying between the orbits of Mars and Jupiter. There are about 5,000 asteroids known today, of which about 98% are in the "Main Belt" lying between Mars and Jupiter, with an average distance from the Sun of about 2.7 astronomical units, or AU. (The Earth is 1.0 AU from the Sun.) Of the remaining two percent known as the near-Earth asteroids, about 90% orbit closer to Mars than to the Earth. Collectively, these asteroids represent an enormous stockpile of mineral wealth in the form of platinum group and other valuable metals.

Miners operating among the asteroids will be unable to produce their necessary supplies locally. There will thus be a need to export food and other necessary goods from either Earth or Mars to the Main Belt. Mars has an overwhelming positional advantage as a location from which to conduct such trade.

Historical Analogies

The primary analogy I wish to draw is that Mars is to the new age of exploration as North America was to the last. The Earth's Moon, close to the metropolitan planet but impoverished in resources, compares to Greenland. Other destinations, such as the Main Belt asteroids, may be rich in potential future exports to Earth but lack the preconditions for the creation of a fully developed indigenous society; these compare to the West Indies. Only Mars has the full set of resources required to develop a native civilization, and only Mars is a viable target for true colonization. Like America in its relationship to Britain and the West Indies, Mars has a positional advantage that will allow it to participate in a useful way to support extractive activities on behalf of Earth in the asteroid belt and elsewhere.

But despite the shortsighted calculations of eighteenth-century European statesmen and financiers, the true value of America never was as a logistical support base for West Indies sugar and spice trade, inland fur trade, or as a potential market for manufactured goods. The true value of America was as the future home for a new branch of human civilization, one that as a combined result of its humanistic antecedents and its frontier conditions was able to develop into the most powerful engine for human progress and economic growth the world had ever seen. The wealth of America was in fact that she could support people, and that the right kind of people chose to go to her. People create wealth. People are wealth and power. Every feature of Frontier American life that acted to create a practical can-do culture of innovating people will apply to Mars a hundred-fold.

Mars is a harsher place than any on Earth. But provided one can survive the regimen, it is the toughest schools that are the best. The Martians shall do well.

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