Mars: America's New Frontier

Robert Zubrin

The time has come for America to set itself a bold new goal in space. The recent celebrations of the 25th anniversary of the Apollo Moon landings have reminded us of what we as a nation were once able to accomplish, and by so doing have put the question to us: are we still a nation of pioneers? Do we choose to make the efforts required to continue to be the vanguard of human progress, a people of the future; or will we allow ourselves to be a people of the past, one whose accomplishments are celebrated not in newspapers, but in museums? There can be no progress without a goal. The American space program, begun so brilliantly with Apollo and its associated programs, has spent most of the subsequent 20 years without a central goal. We need such an overriding goal to drive our space program forward. At this point of history, that goal can only be the human exploration and settlement of Mars.

Some have said that a human mission to Mars is a venture for the far future, a task for “the next generation.” Such a point of view has absolutely no basis in fact. On the contrary, the United States has in hand, today, all the technologies required for undertaking an aggressive, continuing program of human Mars exploration, with the first piloted mission reaching the Red Planet Mars within a decade. We do not need to build giant spaceships embodying futuristic technologies in order to go to Mars. We can reach the Red Planet with relatively small spacecraft launched directly to Mars by boosters embodying the same technology that carried astronauts to the Moon more than a quarter-century ago. The key to success comes from following a travel light and live off the land strategy that has well-served explorers over the centuries humanity has wandered and searched the globe.

Going Native: The Fast Track to Mars

Down through history, it has generally been the case that those explorers and settlers who took the trouble to study the methods of survival and travel of the wilderness's natives were able to get a lot farther than those who did not. The reason for this is that indigenous peoples frequently possessed the best knowledge of how to recognize and utilize resources present in the wilderness environment.

For example, to the eye of an inhabitant of urban civilization, an Arctic landscape is desolate, resourceless, and impassable: yet to an Eskimo it is rich. Thus, during the 19th Century, the British Navy sent flotillas of steam powered warships, at great expense, to explore the Canadian arctic for the Northwest Passage. Loaded with coal and supplies, these expeditions would battle forward against the ice packs for several years at a time, until shortages would force an about-face or cause the entire mission to perish.

In contrast, Amundsen, the first westerner to succeed in forcing the passage, was not afraid to learn from the locals. Operating with an old sealing boat and a miniscule budget, Amundsen had no choice but to adopt a live off the land strategy. So he learned the Eskimo way of Arctic travel - dogsled - which gave him the mobility required to effectively hunt Caribou. He learned about the anti-scurvey qualities of Caribou entrails and uncooked blubber, and he learned about the Eskimo way of building shelters - out of ice. By making intelligent use of local resources Amundsen not only survived and forced the Northwest passage on a shoestring, he was even able to explore widely enough to make some important scientific discoveries, including the fact that the Earth's magnetic poles move.

Is there a lesson in all of this for space exploration? I think there is. Now, there are no Martians - yet, but if there are to be, let us ask ourselves some questions. How will they travel? How will they survive? Will they import their rocket fuel from Earth? How about their oxygen?

When on Mars, do as the Martians will do.

To Mars via Dogsled

There have been a large number of concepts advanced for manned Mars missions that are analogous to the ponderous Royal Navy approach to arctic exploration cited above. Grand ships are required, hauling out to Mars all the supplies and propellant that will be needed for the entire mission. Because such ships are too large to be launched in one piece, construction on orbit is required, as is long term orbital storage of cryogenic propellant. Large orbiting facilities are required to enable both of these operations, and the cost of the whole project goes out of sight.

However, as in the case of arctic exploration, there is a different way a Mars mission can be approached, a "dogsled" way if you will, that by making intelligent use of the resources available in the environment to be explored, allows the logistical requirements for launching the mission to be reduced to the point where the endeavor becomes practical.

This is the spirit of the "Mars Direct" plan. In this plan, no large interplanetary spaceships are used, and thus no orbiting space bases are needed to construct and service them. Instead, the astronauts in their habitat are sent direct to Mars by the upper stage of the same booster rocket that lifted them to Earth orbit, in just the same way as the Apollo missions and all unmanned interplanetary probes launched to-date were flown. While granting the attractiveness of the simplicity of such a scheme, conventional wisdom would deem it infeasible, as the mass of propellant and supplies needed for a manned Mars mission is much too large to be launched in such a way. Conventional wisdom would be right except for one thing: if done in a clever way, most of the propellant and supplies needed for the mission do no have to be launched from Earth at all. They can be found on Mars.

Here's how the Mars Direct plan works. At an early launch opportunity, for example 2003, a single heavy lift booster with a capability equal to that of the Saturn V used during the Apollo program is launched off Cape Canaveral and uses its upper stage to throw a 40 tonne unmanned payload onto a trajectory to Mars. Arriving at Mars 8 months later, it uses friction between its aeroshield and Mars' atmosphere to brake itself into orbit around Mars, and then lands with the help of a parachute. This payload is the Earth Return Vehicle (ERV), and it flies out to Mars with its two methane/oxygen driven rocket propulsion stages unfueled. It also has with it 6 tonnes of liquid hydrogen cargo, a 100 kilowatt nuclear reactor mounted in the back of a methane/oxygen driven light truck, a small set of compressors and automated chemical processing unit, and a few small scientific rovers.

As soon as landing is accomplished, the truck is telerobotically driven a few hundred meters away from the site, and the reactor is deployed to provide power to the compressors and chemical processing unit. The hydrogen brought from Earth can be quickly reacted with the Martian atmosphere, which is 95% carbon dioxide gas (CO_2), to produce methane and water, and this eliminates the need for long term storage of cryogenic hydrogen on the planet's surface. The methane so produced is liquefied and stored, while the water is electrolysed to produce oxygen, which is stored, and hydrogen, which is recycled through the methanator. Ultimately these two reactions (methanation and water electrolysis) produce 24 tonnes of methane and 48 tonnes of oxygen. Since this is not enough oxygen to burn the methane at its optimal mixture ratio, an additional 36 tonnes of oxygen is produced via direct dissociation of Martian CO_2. The entire process takes 10 months, at the conclusion of which a total of 108 tonnes of methane/oxygen bipropellant will have been generated. This represents a leverage of 18:1 of Martian propellant produced compared to the hydrogen brought from Earth needed to create it. Ninety-six tonnes of the bipropellant will be used to fuel the ERV, while 12 tonnes are available to support the use of high powered chemically fueled long range ground vehicles. Large additional stockpiles of oxygen can also be produced, both for breathing and for turning into water by combination with hydrogen brought from Earth. Since water is 89% oxygen (by weight), and since the larger part of most foodstuffs is water, this greatly reduces the amount of life support consumables that need to be hauled from Earth.

The propellant production having been successfully completed, in 2005 two more boosters lift off the Cape and throw their 40 tonne payloads towards Mars. One of the payloads is an unmanned fuel-factory/ERV just like the one launched in 2003, the other is a habitation module containing a crew of 4, a mixture of whole food and dehydrated provisions sufficient for 3 years, and a pressurized methane/oxygen driven ground rover. On the way out to Mars, artificial gravity can be provided to the crew by extending a tether between the habitat and the burnt out booster upper stage, and spinning the assembly. Upon arrival, the manned craft drops the tether, aerobrakes, and then lands at the 2003 landing site where a fully fueled ERV and fully characterized and beaconed landing site await it. With the help of such navigational aids, the crew should be able to land right on the spot; but if the landing is off course by tens or even hundreds of miles, the crew can still achieve the surface rendezvous by driving over in their rover; if they are off by thousands of miles, the second ERV provides a backup. However assuming the landing and rendezvous at site number 1 is achieved as planned, the second ERV will land several hundred miles away to start making propellant for the 2007 mission, which in turn will fly out with an additional ERV to open up Mars landing site number 3. Thus every other year 2 heavy lift boosters are launched, one to land a crew, and the other to prepare a site for the next mission, for an average launch rate of just 1 booster per year to pursue a continuing program of Mars exploration. This is only about 15% of the rate that the U.S. currently launches Space Shuttles, and is clearly affordable. In effect, this dogsled approach removes the manned Mars mission from the realm of mega-fantasy and reduces it to practice as a task of comparable difficulty to that faced in launching the Apollo missions to the Moon.

The crew will stay on the surface for 1.5 years, taking advantage of the mobility afforded by the high powered chemically driven ground vehicles to accomplish a great deal of surface exploration. With an 12 tonne surface fuel stockpile, they have the capability for over 14,000 miles worth of traverse before they leave, giving them the kind of mobility necessary to conduct a serious seach for evidence of past or present life on Mars - an investigation key to revealing whether lfe is a phenomenon unique to Earth or general throughout the universe. Since no-one has been left in orbit, the entire crew will have available to them the natural gravity and protection against cosmic rays and solar radiation afforded by the Martian environment, and thus there will not be the strong driver for a quick return to Earth that plagues conventional Mars mission plans based upon orbiting mother-ships with small landing parties. At the conclusion of their stay, the crew returns to Earth in a direct flight from the Martian surface in the ERV. As the series of missions progresses, a string of small bases is left behind on the Martian surface, opening up broad stretches of territory to human cognizance.

We Can Do It

Such is the basic Mars Direct plan. In 1990, when it was first put forward, it was viewed as too radical for NASA to consider seriously, but over the past couple of years with the encouragement of former NASA Associate Administrator for Exploration Mike Griffin and current NASA Administrator Dan Goldin, the group at Johnson Space Center in charge of designing human Mars missions decided to take a good hard look at it. They produced a detailed study of a Design Reference Mission based on the Mars Direct plan but scaled up about a factor of 2 in expedition size compared to the original concept. They then produced a cost estimate for what a Mars exploration program based upon this expanded Mars Direct would cost. Their result; $50 billion, with the estimate produced by the same costing group that assigned a $400 billion price tag to the traditional cumbersome approach to human Mars exploration embodied in NASA's 1989 "90 Day Report."

In essence, by taking advantage of the most obvious local resource available on Mars- its atmosphere- the plan allows us to accomplish a manned Mars mission with what amounts to a Lunar-class transportation system. By eliminating any requirement to introduce a new order of technology and complexity of operations beyond those needed for Lunar transportation to accomplish piloted Mars missions, the plan can reduce costs by an order of magnitude and advance the schedule for the human exploration of Mars by a generation.

Exploring Mars requires no miraculous new technologies, no orbiting spaceports, and no gigantic interplanetary space cruisers. We can establish our first small outpost on Mars within a decade. We and not some future generation can have the eternal honor of being the first pioneers of this new world for humanity. All that's needed is present day technology, some 19th century industrial chemistry, and a little bit of moxie.

Mars: America's New Frontier-Sidebar-1

Colonizing Mars.

Enhanced by a third stage employing the same kind of nuclear thermal rocket technology that was demonstrated in the United States in the 1960's a single heavy lift booster would be able to send 24 people one way directly to Mars. If eight such boosters are launched per year, (the same rate that the U.S. now launches space shuttles) the Martian population would grow at a rate comparable to that of colonial North America during the 17th Century. Thus, from the point of view of transportation technology, Mars is as viable a target for colonization today as North America was in 1600.

The question of colonizing Mars is thus not one of transportation, but of the ability to use Martian resources to support an expanding population. The technologies required to do this will be developed at the first Mars base, which will thus act as the beachhead for the wave of immigrants to follow. Initial Mars Direct exploration missions approach Mars in an manner analogous to terrestrial hunter-gatherers, and utilize only its most readily available resource, the atmosphere, to meet the basic needs of fuel and oxygen. In contrast, a permanently staffed base will approach Mars from the standpoint of agricultural and industrial society. It will develop techniques for extracting water out of the soil, for conducting increasingly large scale greenhouse agriculture, for making ceramics, metals, glasses and plastics out of local materials, and constructing large pressurized structures for human habitation and industrial and agricultural activity.

Over time, the base will transform itself into a small town. The high cost of transportation between Earth and Mars will put a strong financial incentive to find astronauts willing to extend their surface stay beyond the basic one and a half year tour of duty, to four years, six years, and more. Experiments have already been done showing that plants can be grown in greenhouses filled with CO_2 at Martian pressures; the Martian settlers will thus be able to set up large inflatable greenhouses to provide the food required to feed an expanding resident population. Mobile microwave units will be used to extract water from Mars' permafrost amd soil, supporting such agriculture and making possible the manufacture of large amounts of brick and concrete, the key materials required for building of large pressurized structures. While the base will start as an interconnected network of Mars Direct style "tuna can" habitats, by its second decade much larger pressurized structures of native brick and concrete will be available.

But the future of Martian colonists will not be to live in dark tunnels. Because the Martian atmosphere provides adequate protection against solar flares, living on the surface in the light of day will be possible. Moreover, the ability to manufacture brick and concrete will allow colonists to greatly expand their living space by providing foundation material for pressurized domes. The first such domes could be imported from Earth. If made of high strength plastic like kevlar, a 50 meter diameter inflatable dome would only have to be 1 mm thick to contain a skylab-like 5 psi atmosphere with a large safety factor, and would only weigh about 4 tonnes. An additional 4 tonnes of plexiglass cut into equilateral triangles to form a pre-fabricated geodesic dome would also have to be sent. This would be erected as a non-pressurized shield above the inflated pressurized dome to protect it from wind blown dust abrasion and material degradation caused by solar ultra violet light. A hundred meter diameter dome would require 32 tons of kevlar and 16 tonnes of plexiglass; a 200 meter diameter dome would need 256 tonnes of kevlar and 64 tonnes of plexiglass. Importing construction material on these scales would be impractical, but it would not be necessary, as all the raw materials needed to manufacture high strength plastics exist on Mars. As a succession of ever larger domes are built, they will be linked by brick and concrete tunnels. The domes will also create a greenhouse effect, providing a spacious temperate shirt-sleeve residential environment. Within the domes, the colonists will live in red brick or perhaps New Mexico style stucco houses, and plant their gardens. Each new reactor landed will add to the power supply, as will locally produced solar panels and windmills, and as more people steadily arrive and stay longer before they leave, the population of the town will grow. In the course of things, children will be born, and families raised on Mars, the first true colonists of a new branch of human civilization.

While the initial exploration and base building activities on Mars can be supported by government largess, a true colony must eventually become economically self supporting. The Mars colony will be able to do this by exporting both ideas and materials. Just as the labor shortage prevalent in colonial and 19th century America drove the creation of Yankee Ingenuity's flood of inventions, so the conditions of extreme labor shortage combined with a technological culture and the unacceptability of impractical legislative constraints against innovation will 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, will finance Mars even as they revolutionize and advance terrestrial living standards as forcefully as 19th Century American invention changed Europe and ultimately the rest of the world as well.

In addition to inventions though, Mars may also be able to export minerals. Like the Earth, Mars has had a complex geologic history, sufficient to form rich mineral ores. Unlike the Earth, however, Mars has not had people on it for the past 5000 years scavenging all the readily available rich mineral deposits to be found on its surface. Rich, untapped mineral deposits of gold, silver, uranium, platinum, palladium, and other precious metals may all exist on the Martian surface.

If Mars has valuable minerals, the colonists will be able to use rocket hoppers using locally produced propellants to lift them from the Martian surface to Phobos, where an electromagnetic catapult can be emplaced capable of firing the cargo off to Earth for export. Alternatively, on Mars it will also be possible to build a “skyhook” consisting of a cable whose center of mass is located at a distance from which it will orbit the planet in synchrony with Mars’ daily rotation. To an observer on the Martian surface such cables will appear to stand motionless, allowing payloads to be delivered to space via cable car. Because of strength of materials limits, such systems cannot be built on Earth, but in Mars’ 3/8 gravity they may well be feasible. If so, they would give the Mars colonists unique ability not merely to transport goods to Earth, but to access the resources present throughout the rest of the solar system. Mars will become the central base and port of call for exploration and commerce heading out to the asteroid belt, the outer solar system, and beyond.

Life in the initial Mars settlements will be harder than life on Earth for most people, but life in the first North American colonies was much harder than life in Europe as well. People will go to Mars for many of the same reasons they went to colonial America: because they want to make a mark, or to make a new start, or because they are members of groups who are persecuted on Earth, or because they are members of groups who want to create a society according to their own principles. Many kinds of people will go, with many kinds of skills, but all who go will be people who are willing to take a chance to do something important with their lives. Out of such people are great projects made and great causes won. Aided by ever advancing technology, such people can transform a planet and bring a dead world to life.