#2 March 31, 2017

Continuing our look at Mars:
Who should be the first Martian Explorers?

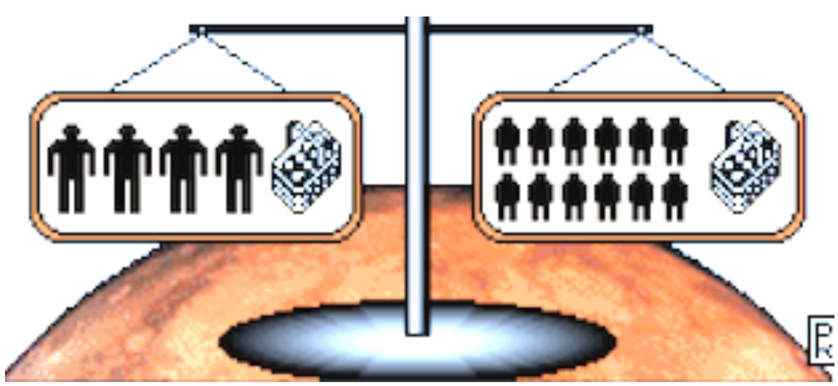
A Bold Tack in Choosing the 1st Mars-bound Crews

The obvious choice? a crew of healthy persons representative of participating nations.

- **There could hardly be a more striking instance of the obvious tack being "dead wrong".**
- Every aspect of the Mars mission can be designed so that "**brains are everything, and brawn irrelevant.**"
- We can send more "**Little People**" with the same supplies and thus accomplish much more mission for our precious bucks.

"More to Mars"

Sending 12 men to Mars for the price of 6, 24 for the price of 12:
A Radical First Exploration Mission Plan not to be lightly dismissed



By Peter Kokh

Some years ago Robert Zubrin first showed us how to get much more Mars mission for our buck, in his "Mars Direct" mission plan proposal. We could make the fuel for the Earth-return leg on Mars itself, while bringing that fuel along with us to Mars would either mean much heavier and more expensive ships, less equipment to use on Mars, or both.

Now it is time to show that there is **a "Mars Direct" "compatible" mission plan option that could double or triple the size of the crew - virtually for free** - resulting in a first Mars exploration mission with **two to three times as much productivity.** We call this the "**More to Mars**" mission architecture.

All previous Mars mission plans assume without examination that crew personnel would be selected according to established NASA standards in all respects. Built into these standards is a self-hidden visceral chauvinism that does not let us examine other options, <u>nor even suspect they exist</u>.

But in looking for a better way to do Mars, this hidden parameter deserves as much attention as any other.

International Space Station Standards

The American and Soviet space programs have naturally been evolved from Air Force pilot standards. Planes have one or more "standard size" seats. Likewise, the Space Station has a number of standard cubicles. Astronauts. both male and female, have been in a common height and weight range. And the seats in the U.S. Space Shuttle and Russian vehicles have been designed to carry astronauts and cosmonauts of common adult sizes.

We need not follow suite in designing Mars-bound space craft.

It is time to take a second look at crew person standards we have long taken for granted. Going to Mars is a whole different story.

Mars-bound trips will be expensive as well as of long duration.

What if there was a way to send twice as many people to Mars for the same price, in a same size craft?

If we could do this, the crew, on arriving at Mars, could accomplish twice as much: establishing an outpost with twice the crew and accomplish twice as much in the same amount of precious time.. Certainly, this would be the way to go.

The answer should be obvious: <u>pick crew members of half the weight of what NASA and other space agencies have taken for granted.</u>

Twice as many hands, twice as much brains, twice the output

"Little people"? Dwarfs?, Pygmies? - the standard is clear: each individual chosen should have as much talent, ability, and inventiveness as crew personal twice their weight. They would accomplish twice as much as a crew of "standard" height and weight.

This does not mean that "standard-sized" humans will never go to Mars.

But it should mean that your ticket price should reflect the cost and space-taking size of your berth, and the expectation that you can only accomplish half as much - for the amount of fuel needed to get you to Mars (and back) and for the twice as much food that it takes to sustain you.

Twenty-four years ago, in MMM # 64 April '93, in our annual "World Watch" by **AFD* News Service** (* April Fools Day), we ran the following "news story."

BOULDER, COLORADO: Pygmies and Dwarfs should crew our first exploratory missions to Mars say Doctors Erin Keebler* and Tung Yhn Tshieq* of the Willy Ley Institute in a report to the National Space Council which they will present at next month's Case For Mars V Conference in Boulder, CO. (*fictional names)

Pygmies and Dwarfs, or "Little People" as they are now more commonly called, have greatly diminished body mass but fully normal brain size and intelligence. The Mars Mission, they say, can easily be engineered so that "**brains count for almost everything, brawn for next to nothing."** A crew with a combined body mass 25% that of the average astronaut crew of the same number would have a tremendous advantage in two ways. First the crew would need only a weight-proportionate amount of consumables: food, water, fresh air reserves.

Second, while the mass and volume of needed spaceship systems and work stations would remain unchanged, the size, volume, and associated mass of both private and common quarters and walk space could be proportionately reduced. The authors contend that for otherwise identical missions, one crewed by Little People and designed to be so, would have a fueled launch weight 40% less than one planned for full-size crew members.

This savings can either be reflected in √ a cheaper, quicker mission, or "cashed in" for √ extra payload and a longer duration stay on Mars, or for √ a larger crew. This becomes a**n attractive win-win-win situation.**

The only drawback, the authors admit, is the need to sell the idea to a public that has not ever really accepted either Pygmies or "Little People" as real people.

For individual space supporters, the vicarious pleasure of identifying with our pioneers and explorers is a big element and the choice of so 'unrepresentative' a crew could demand an overdue attitude shift. - AFD News Service

In fact, we were dead serious about this proposal.

Yet the disheartening lack of subsequent feedback to this article only served to show how most readers apparently took it, as "a joke." Yes, a sad joke on them (on you also, if the shoe fits!) The hint not taken 24 years ago, it is now time to declare ownership of this idea and to publish it anew.

This is one of those times, dear reader, to either lead, follow, or get out of the way.

As pointed out in our "tongue-in-cheek" AFD story, the substantial weight savings from selecting substantially smaller humans of undiminished capacities and abilities can be "spent" in three ways:

- Less massive Mars ships, same size crew mission
- Same size ships, more equipment, more consumables, longer stay
- Same size ships, larger crew, larger task load

√ If the cost of the first Mars mission is a major political stumbling block, the same size "ground mission" can be achieved with a smaller rocket and less fuel - at substantial cost savings.

√ If the government(s) has (have) accepted conventional costing, what we get for that price can be doubled or tripled by either remaining option.

Two objections sure to arise to such a plan are the following, neither of them defensible:

- **"Subsize humans have inferior intellects and lesser technical and manual abilities"**
- **"The public will never identify with these "toy" sized humans and thus lose interest."**

The first objection is truly facetious. There is plenty of time before the first manned Mars mission to identify young dwarf, Pygmy, or other small and lightweight individuals **with the sufficient aptitude**, and then to **educate and train them from early youth** to perform **as outstandingly as any more physically advantaged candidates**.

The second objection is reminiscent of racist objections to the introduction of blacks into the major sports. Sports history in the past half century gives this thesis the lie. **The public willingly and very quickly takes to its heart anyone who performs in outstanding fashion.** Some of us would sell the public short, perhaps to disguise hidden unexamined attitudes in ourselves.

I am not suggesting here that Mars be settled exclusively with diminutive individuals, only that making our initial exploration crew selection from their ranks could be the smartest thing we could do. – **establish a substantial beachhead for far less money**.

In time, improved transportation options will make emigration to Mars affordable to individuals of more commonplace stature and body mass.

"The" important thing, however, is to break the ice on Mars, and to do as much pioneer scouting and pave-the-way scientific investigation as possible in one shot given the money available, so as to lead to the opening of the Mars Frontier in the timeliest fashion possible.

Yes, this would be a bold tack in casting the 1st Mars Crew

To most people, not ever thinking of such options, the "obvious" choice would be to pick a crew of healthy persons representative of participating nations – hardly be a more striking instance of the "obvious" tack being "dead wrong,"

Every aspect of the Mars mission can be designed so that brains are everything, brawn irrelevant. We could send more "Little People" with the same supplies and thus accomplish much **more mission for our precious bucks.** "More to Mars" is our best chance to make the most of what may be once in a generation opportunity.

Could prejudice ruin our one best chance?

The purse-holders of the world may not pay for a "second Mars Exploration Mission," whether or not additional missions have been planned as part of a total exploration package. The one thing that is **vitally important is to accomplish all the exploratory and investigative tasks necessary to pave the way for the opening of the Mars Frontier to settlement in the first mission**, lest we get no follow up opportunities.

Whoever thinks that this is not important, has learned nothing from the politics of Apollo. If we do get the chance to send humans to Mars, it may very well be a solitary chance. "More to Mars" is our best chance to make the most of it.

I urge the prospace and pro-Mars communities to take the suggestion as seriously as it is meant, and to constructively brainstorm it further. "More to Mars" is a second watershed in the history of Mars Mission Planning. In the end, through our decisions, we shall deserve what we shall get – as always.

In the process, Little People and/or Pygmies could earn lasting and long overdue respect. Just as their outstanding participation in the performing arts and major sports has won Afro-Americans widespread and genuine respect in today's world, a successful mission to Mars crewed by more diminutive persons will do much to erode the major cultural barriers that these populations now face.

In the end, we must ask ourselves that age-old question:

"Is it better to be on top of a small hill, or half way up a tall mountain?"

In becoming all that man can be, it is vital that we employ all the varied talents that are out our disposal. **Every time we collectively exclude full participation by a minority population, we self-betrayingly choose "the smaller hill".** Dwarfism may be one of humanity's infrequent and most unsuspected talents. A successful one-shot Mars-opening mission lies in the balance.

Three or more millions of years ago, 3 foot tall proto-hominids scouted the way for the human rise to ascendancy on our home planet.

Does it not seem poetically fitting that a "race" of little scouts turn the trick once again - this time on Mars?

Just the facts, please!

Dwarfs are not a race. "Dwarfism" is a nonhereditary genetic condition found among all races. Children of dwarfs who marry are usually of "normal stature". Thus dwarfs are "where you find them". Intelligence and manual dexterity are unaffected. While the "supply" is smaller in terms of numbers, so is average height (less than 3 ft/1 meter) and weight (30-45 lbs.)

Pygmies are members of two "races," the

- 150,000 Negrillos of central Africa, and approximately
- 35,000 Negritos of Southeast Asia and Oceania. (These figures are some years old.)

The former average a half foot shorter (4'-4'8") than the latter (4'6" to 5"). Both these populations are more "normally proportioned" than are "dwarfs," and they are heavier: 60-80 lbs and 80-100 lbs respectively.

The Upshot for a "More to Mars" Mission with a Dwarf and/or Pygmy Crew

- Interior habitat configurations can be made more compact, starting with personal sleeping cubicles, elbow room at work stations, etc.
- Shifts & hot-racking will stretch common spaces, and multiply the in-flight work that gets done.
- Crew quarters can be downsized, making room for larger crews.
- The Mars outpost could be "bigger", staff wise, or we could have outlying tended camps to support more far-ranging exploration and prospecting.
- The list of talents & abilities represented could be doubled, or even tripled.
- The physical mission will be designed to call for hands and brains, not muscles, and there will be more of those.
- One first mission could achieve the goals of three "conventionally-manned" missions.

Its a win-win-win situation! MMM

Today, in mid-2017, our remarks above still seem appropriate.

It will cost a lot of money to send pioneers to Mars, charged with breaking ground on what is to become a new human world.

If there is a way we can send 2 persons (maybe 3, maybe even 4) for the same ship cost and fuel price of 1 person of "average" weight, then we will be able to open this new human frontier in much more timely fashion.

Some of the savings in food, mass of accommodations, etc. can be spent on

√ **sending along more tools,**
√ **building up larger settlements faster,**
√ **exploring more territory in less time**, and on and on.

What "little people" can accomplish depends on their tools, not on their own weight.

Tourists and Visitors to Mars

In time many people will go to Mars, not necessarily to stay, (though some may so decide) but to visit. Their ticket price should not be per person, but per weight and the amount of food and supplies they may need.

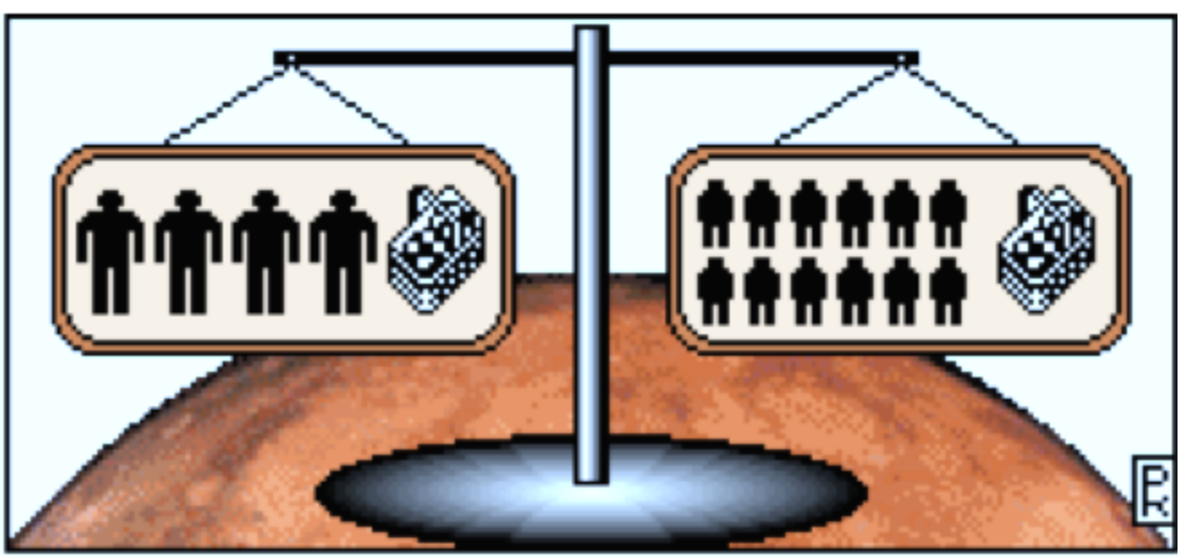
If the spaceship companies bringing them to Mars, choose to set an "average (weight) fits all" price, that will be their choice.

Will some tourists and visitors go on a starvation diet prior to purchasing their one-way or round trip ticket? Perhaps, if it means less rocket fuel and a cheaper ticket.

Me? Well at 79, I am 4" shorter (5'4"), and 15 lbs lighter (140) than I was at the time of my high school graduation. I'd still have to pay a high price.

But instead of saving up money, I choose to "imagineer" – suggest how those with enough years left in their lives to dream of settling or just touring Mars, might do so.

When you get to Mars, say "Hi" for me. **PK**



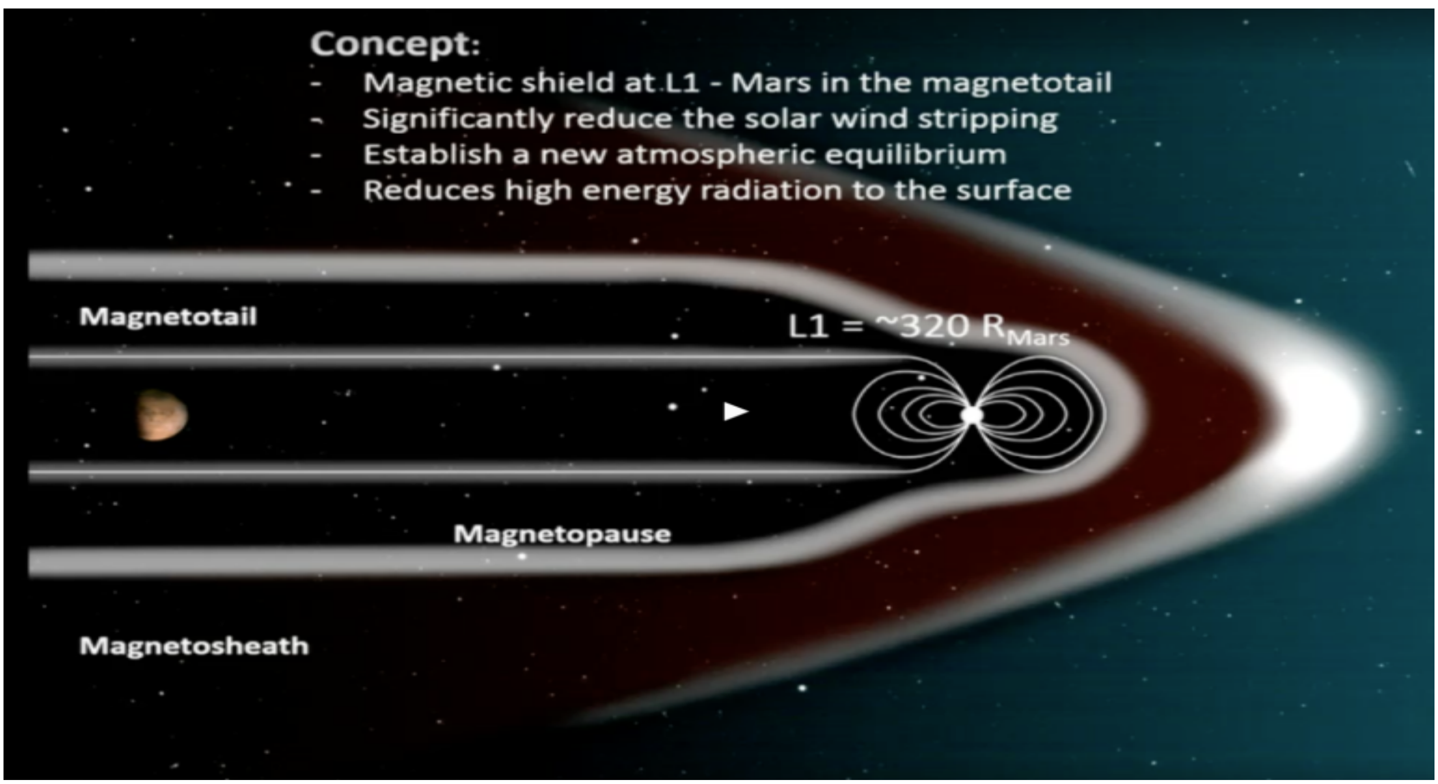
Most Exciting Proposal for "Terraforming" Mars yet!

http://www.popularmechanics.com/space/moon-mars/a25493/magnetic-shield-mars-atmosphere/

NASA Considers "Magnetic Shield" to help Mars "Grow its Atmosphere" – the shield could help warm Mars and possibly allow it to become "habitable."

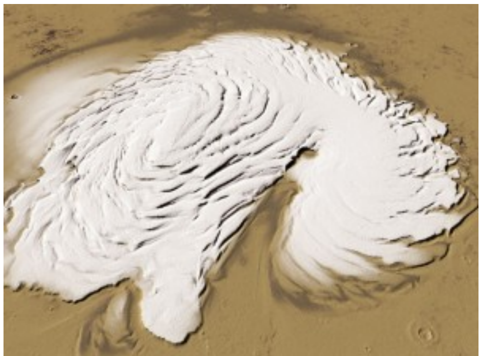
One of the most enticing ideas came this morning [March 1, 2017] from Jim Green, NASA's Planetary Science Division Director. In a talk titled, "A Future Mars Environment for Science and Exploration," Green discussed launching a "magnetic shield" to a stable orbit between Mars and the Sun, called Mars L1, to shield the planet from high-energy solar particles. The shield structure would consist of a large dipole —a closed electric circuit powerful enough to generate an artificial magnetic field.

Such a shield could leave Mars in the relatively protected magnetotail of the magnetic field created by the object, allowing the Red Planet to slowly restore its atmosphere. About 90% of Mars's atmosphere was stripped away by solar particles in the lifetime of the planet, which was likely temperate and had surface water about 3.5 billion years ago.



Such a shield could help Mars achieve half the atmospheric pressure of Earth in a matter of years. With protection from solar winds - the dipole creates a magnetic field roughly as strong as that of Earth

Frozen CO_2 at Mars's polar ice caps would start to sublimate, or turn directly into gas from a solid. The greenhouse effect would start to fill Mars's thin atmosphere and heat the planet, mainly at the equator.



At this point, vast stores of ice under the poles would melt and flood the world's low lands with liquid water.

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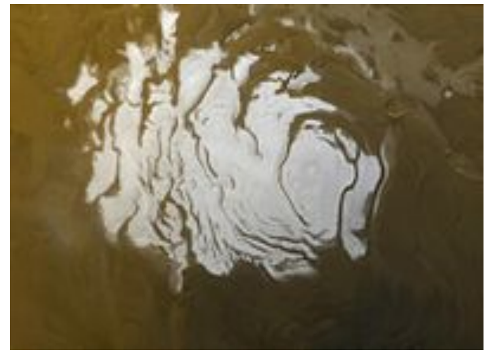

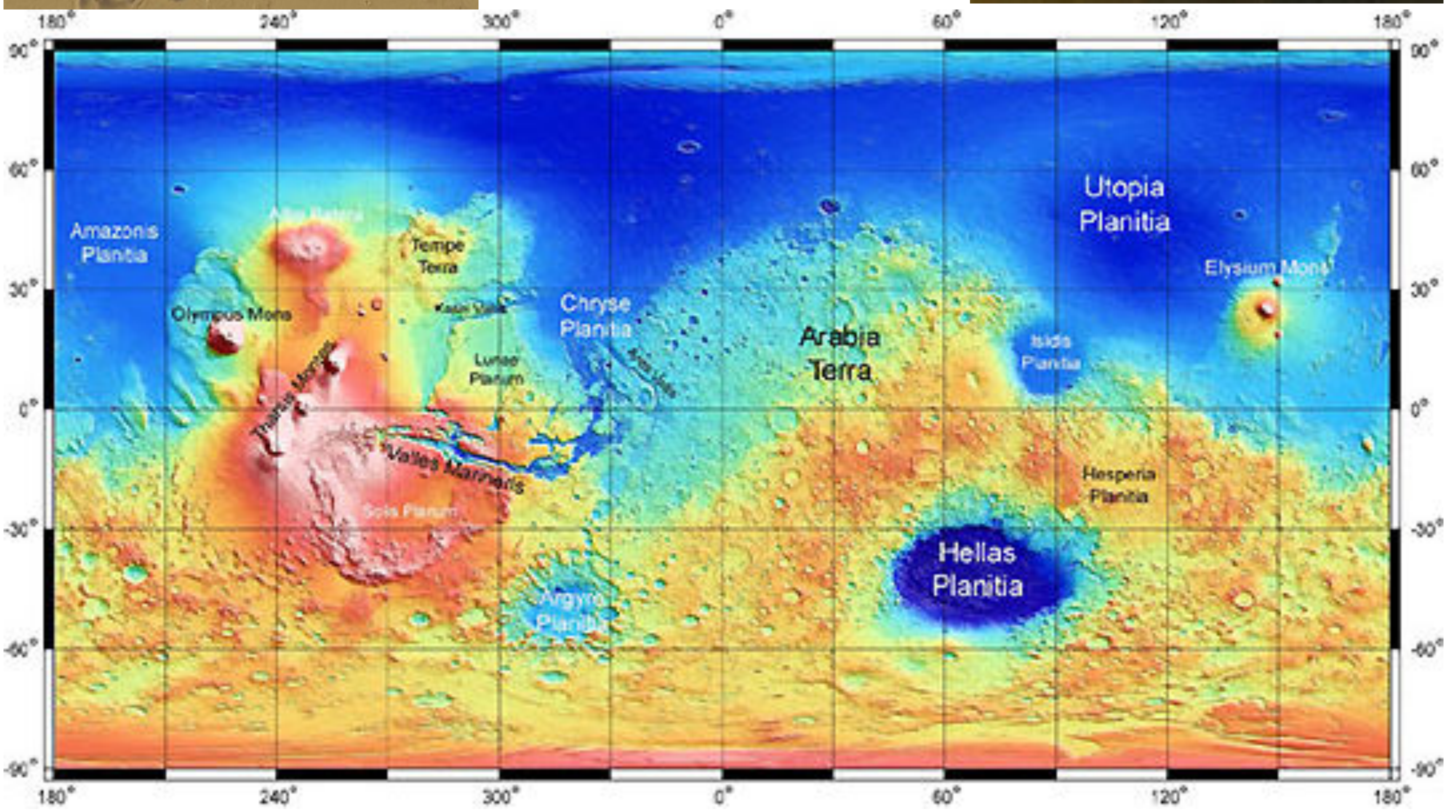

"Perhaps 1/7th of the ancient ocean could return to Mars." ##

Melted ice from the North polar cap would settle in the darker blue areas of the Northern Hemisphere, like **Utopia Planitia**, including, possibly, the depths of **Valles Marineris**. Melted ice from the Southern polar cap would settle in **Hellas Planitia**, the deepest basin on Mars, and perhaps in the shallower **Argyre basin**. ##

Now there was a series of novels by Kim Stanley Robinson: Red Mars, Blue Mars, and Green Mars. But, as I pointed some time ago, he forgot one: "Muddy Mars!" – LOL!

In the meantime, Martian Pioneers would do well to breed plants that will be able to take root as the planet gets "wet" again.

We had written an article about this project, "**Redhousing**" – breeding Mars-hardy plants in compressed Mars Air with the goal of meeting Mars halfway as the planet's atmosphere thickens and as its surface gets wetter. .

You will find it in **http://www.nss.org/settlement/moon/library/mmm_Mars.pdf under the MMM #93 March 1996 section.**

'Redhousing"
Breeding "Mars Hardy" Plants in Compressed Mars Air

By Peter Kokh – (First published, March 1993

It is not precise to say that Mars is "barren." Only that it is "virginal." That is not the end of the story. That Mars has no life, and quite possibly never spawned life even in earlier wetter and warmer times does not make the planet "barren". It only makes the planet "virginal".

That conditions may have never been special enough to allow life to rise on its own, does not mean that life, originated elsewhere, and then bioengineered to fit Martian conditions, could not be successfully transplanted to Martian soil, with intelligent guidance, corrections, and compensations.

That is a tall challenge, however, but we hope to sketch how it might be accomplished; or at least, the first steps one intending to green the planet might take. The biological side of Greening Mars would have to be brought about "pari passu" i.e. step by step, together with the geological rejuvenation of the planet. Rather than "terraforming" Mars by making it a copy of Earth, rejuvenation looks not at Earth, but the early Mars itself, for its standard of achievement.

The planet does need to be warmed, first to the point where a third of the atmosphere no longer freezes out over the poles each winter (twice a Martian year, during northern and southern winters, i.e. paradoxically during southern and northern summers, i.e. atmospheric pressure is at its height only during spring and fall).

Warming it still further will free up additional carbon dioxide bound up at the poles or in permafrost year around.

Both temperature and pressure have to be increased to the point that liquid water can exist in the open, even if only as seasonal dews.

Developing Mars-hardy plants

But in this article, we want to look at the biological part of the equation. Obviously we want to, and must use genetic material from sundry terrestrial plants (possibly animals too) and arrive at species hardy enough to survive and breed on a rejuvenated Mars.

But what we have to start with is, species after species, a long way from being remotely Mars-hardy. The harshest most demanding habitats on Earth are all much friendlier than the friendliest place on Mars, even possibly on the wetter, warmer Mars of "yestereon".

Where do we start? How do we proceed?

The most severe habitats on Earth are the deserts, the Andean altiplano of Peru and Bolivia, the tundra of northern Alaska, Canada, Greenland, Scandinavia, and Russia-Siberia, and the Antarctic islands, shores, and "dry valleys." No trees grow in these areas, not even the stunted, wind-grotesqued caricatures we find at the tree line on mountain slopes and at the tundra limits.

Animals fare better, thriving on seafood, other animals and very lowly plants.

But while animals need an oxygen-rich atmosphere, which Mars has never had, plants thrive on carbon dioxide – it has been shown that most plants can be grown successfully in an artificial atmosphere of reduced pressure (e.g. 1/10th normal) of just carbon dioxide, the major component of Mars air. That is, plants and crops can be grown on Mars in greenhouses pressurized with warmed Martian atmosphere, simply compressed tenfold – nothing else added, besides water.

The general idea is that we could gradually lower temperature and pressure in labs here on Earth to meet the improving Mars climate halfway with bioengineered species that could be planted outdoors either to be tended and cultivated or left to grow wild.

We call this redhousing, rather than greenhousing. We are using the air of the red planet Mars and an improved but still Martian climate – not the air of Earth and an idealized terrestrial climate. This is not to say we shouldn't have traditional greenhouses on Mars. We do have to eat and clothe ourselves and provide for pharmaceuticals and other needs, day in and day out – while we are busy in the redhouses preparing to mate a rejuvenated red planet with a blanket of life bred and engineered "to go native" there.

Will there someday be forests on Mars, with real trees even if they look unearthly. That's a possibility beyond our vision. Our starting point will likely be the lichen, a moss-like plant that is basically a fungus able to survive thanks to a symbiotic relationship with green algae. That this feat is cooperative is discouraging, that we have to start with a very specialized complex – compound creature. The best place to start in any plan aimed at evolving a radiant family of diverse species is with something very generalized, able to survive in a wide range of habitats. But thankfully, we have many species of lichens in the northern hemisphere and a few in the southern.

But are lichens the only starting point? Not necessarily. Many plants handle annual freezing in stride, but the much longer, much deeper freezes of Mars would likely be too much for them. Witness tree lines in northern Alaska, Canada, Scandinavia, Russia-Siberia!

From animals to plants

Some antarctic organisms in the animal kingdom, come equipped with an intracellular antifreeze – glycol. But plant cells have protoplasm as well. If such an intracellular glycol could be transferred successfully to some plants, that might give us additional breeding stock for Mars. The more starting points, the more diverse the ultimate possibilities, the more niches on Mars that can be greened.

But hard long freezes are not the only challenges Mars poses. Severe desiccation is another. Desert plants, like cacti and other "succulents" withstand prolonged very arid stretches well. The desiccating capacity of the cold parched winds is extremely intense. What the cacti and other desert plants have to offer, will not be enough.

But it is a start. Nor is there any reason why the glycol gene cannot be added to the genetic consist of desiccation-hardy plants, and vice versa. Chile's Atacama, California's Death Valley, NW China's Takla Maklan are the most challenging niches for desert life.

Ultraviolet life-killing rays

And then there is the untempered ultraviolet of the more distant, cooler, Martian "Sun". Mars tenuous atmosphere without free oxygen (O_2) or ozone (O_3) is transparent to this tissue- killing radiation. Here on Earth, the most UV-resistant species are those that live at very high altitudes. The nearer to the equator, the higher up the maintain slopes does life thrive. Plants growing wild in various niches of the Peruvian-Bolivian altiplano (high altitude 13,000-15,000 ft. intermountain basin-plateau between the Western and Eastern Cordillera) may yield genetic contributors to this resistance. — a third ingredient.

The challenge of pollination

We must add one more characteristic. On Earth many plants are pollinated by insects and birds. Bioengineering animals to breath a carbon dioxide atmosphere seems science-fantastic, not merely science-fictional. We may want to end up with plants that are wind-pollinated or use some other assist other than the help of sweet air breathing animals.

The list of favorable attributes doesn't end here. We could select also for:

- abrasion resistance to wind-borne dust
- low reproductive rates
- interruptible life cycles, etc.

What plant forms will be most receptive to such diverse genetic additions? Your guess is as good as ours. It is not impossible that the best Mars-hardy hybrids will have as ancestors plants that boast none of those assets, but will have proven receptive to all of them.

Nor do we have to wait until we are on Mars to begin the experimenting. There are so many candidate plants to start with, so many recombinant genetic combinations to be tried. The sooner we begin, and the more the facilities we set up, the sooner are we likely to have our optimism and enthusiasm rewarded - or discouraged.

On Mars, all we will need is a shelter that holds compressed, warmed Martian air. On Earth it will be a little trickier. Unbuffered, the facility would be subject to inexorable leaks from the higher pressure, vastly more oxygen-sweet air of the host planet. We can buffer the facility and prevent hasty degradation of the special atmosphere within, by using a surround chamber with either Earth air or Mars air at relatively low pressure. Air would tend to leak out of the red house chamber, preserving quality, with makeup quantities from special tanks. If pressure in the surround got to high (too close in value to that of the inner chamber) the excess could be pump- exhausted to the outside terrestrial atmosphere.

Or the redhouse could be covered and buffered by water in a host lake or pool or tank to prevent atmospheric contamination. A wet porch could not be used for entry - oxygen dissolved in the water would outgas into the carbon dioxide atmosphere within, polluting it.

An Art of the Possible

The strategy is one of convergence, breeding ever more cold-, drought-, and UV-hardy species for ever more Mars-like conditions in 'redhouses. Outside the actual Mars climate is improved by human activity and intervention. In fact, the degree to which these experiments are successful, will codetermine the goals set for rejuvenaissance of the planet.

Like politics, the greening of Mars will unfold as the art of the possible. As politics should be (but isn't) it will also be the art of "co-promise," not "com-promise" - that is what can be achieved in improving the climate, temperature, pressure, and wetness of the planet - and what can be achieved by recombinant DNA biological engineering and breeding for Mars-hardiness. We can only speculate at the results.

The Role of Intervention:

On Earth, and most likely on all life-bearing planets, evolution has not been smooth. Each outburst of new species origination slows into a self-stabilizing rut, impeding further progress. It is the periodic decimation of existing species by comet and asteroid impacts that has cleared the way for new evolutionary growth.

The future of redhousing will include man-made catastrophes to severely purge prematurely stabilizing indoor ecosystems and clear the way for new rounds of the game of survival of the most (man-determined) fittest.

Redhousing: the Plan for Mars and the Grand Design of Things

As progress allows us to preview eventual results, we will learn what areas of Mars to set aside as future areozoic parks and preserves. Low-elevation basins and canyons will have the highest atmospheric pressure, the warmest temperatures (latitude for latitude) and be the first to experience dews and free standing and/or flowing open water.

To return to the point we made at the outset,

"If Mars is devoid of life, that makes it a virgin world, not a barren one."

The cosmic vocation of humanity, may indeed be

to bring life to places where it can survive, but never originate on its own.

Only an intelligent species can serve this function. Humanity then becomes "the" reproductive organ of Gaia (Earth-Life in aggregate).

Further, through interstellar flight, even if it only be of ships bearing nothing more than seeds, spores, and fertilized eggs, this particular human vocation takes on a more general "Cosmic significance", in the Solar neighborhood (probe-reachable limits to be determined!) beyond this nursery womb-world nano-turf we call Earth. ##

Plants will be grown in greenhouses, but also in "Living Walls" which can line pressurized walkways between habitat and activity modules, as well as serving as room dividers.
On Mars, and on the Moon and everywhere else humans settle, we can't have too much vegetation, be it just foiage, or fruit, vegetables, and not to forget flowers and pollinators.

AFD NEWS **WORLDS WATCH** SERVICE

"Planet 9", on the outer fringe of the Solar System, could well be a hollow shell: Scientists are perplexed after finding a moon that orbits the large Saturn-sized planet considerably slower than if Planet 9 were an "ordinary" gas giant. This would seem to suggest that the planet is an artifact created by "visitors" from afar, perhaps eons ago. At the least, we can take it as encouragement for our own "star-faring" ambitions.

A Lake on Saturn's Mercury-sized moon Titan appears to have "something" "swimming" in it - not floating with the surface currents. Ligeria Mare, a lake in the north polar region of Titan, is the second largest known body of liquid on Titan. Larger than our own Lake Superior, it is mostly composed of liquid methane, with unknown but lesser components of dissolved nitrogen and ethane, as well as other organic compounds. Roughly 420 km (260 mi) by 350 km (217 mi) across, it has a surface area about 126,000 km^2.

Now scientists have observed "irregular dark shapes" a few meters across, moving across current, sometimes even upstream. That these moving "shapes" are living creatures of some "hyper-exotic" kind would seem to the only explanation. The biology and tissues involved must be quite exotic by our standards.

Chemical analysis of Europa's maze of rust-colored streaks suggests that they must be made of organic compounds, a clear indication that the ocean below hosts living organisms and creatures of some type. With countless thousands of such streaks covering the surface, the ice crust must crack relatively frequently in geological terms. It would take a landed party of biologists to find clues to what types of living creatures inhabit the ocean below. The working assumption is that they are likely to be quite primitive

Finding life on Europa would suggest that Europa-type worlds which can form around any gas giant planet, even around Brown Dwarf stars, must be the prevalent type of life in the universe, however "dead-ended" in its evolution.

A subglacial "lake shore" on Greenland reveals ruins of an advanced settlement, possibly built by alien "visitors" several hundreds of thousands of years ago, before the most recent ice age covered the world's biggest island with thousands of feet of ice. Scientists hope to find in these ruins clues about their alien civilization, as well as what they may have looked like, and maybe even indications of where they came from.

Happy April Fools' Day - MMM's 29th April Fools Day News Release!

Accessing Lunar and Asteroidal Resources

by Dave Dietzler

The Low delta V Trap

It is commonly argued that it take less delta V to reach numerous Near Earth Objects (NEOs) consisting of various types of asteroids and some old comets or even the planet Mars than it does to reach the surface of the Moon. In terms of energy and propellant, NEOs and Mars are “closer” than the surface of the Moon. However, this only really matters if all rocket fuel is coming from Earth. With inexpensive space resources the picture changes. If propellant from the Moon or asteroids is available, the high cost of rocketing massive payloads of propellant to LEO is avoided. Also, the Moon is only a few days away and NEOs and Mars are months, even years away. Launch windows to and from Mars via low energy trajectories come about roughly every two years and launch windows to and from NEOs can be years apart. There isn't much published data about launch windows and trajectories to and from NEOs. Launch windows are based on the synodic period which is the time it takes two orbiting bodies to repeat the same angular positions relative to each other. The closer the orbital periods are the longer the synodic periods, therefore the closer two objects are the longer the time between launch windows.

Asteroid Orbital Period in Years	Synodic Period in Years
0.6	1.5
0.7	2.33
0.8	4
0.9	9
0.95	19
1.05	21
1.1	11
1.2	6
1.3	4.33
1.4	3.5
1.5	3
1.6	2.67
1.7	2.43
1.8	2.25
1.9	2.11
2 0	2

Based on dV alone it is said that NEOs and Mars are “easier” to reach than the surface of the Moon. This completely ignores time factors and the challenges of long term life support, weightlessness and radiation exposure. Tossing around the words, "easy" or "easier" just because the total dV is lower is misleading. First of all, with electric drives propellant isn't that big a deal so how much money is really saved? Time is important. How long does it take to get to these "easy" NEOs and how far apart in time are launch windows? Surviving in space for great lengths of time is no easy task.

Where Are All the Customers?

Then who do you sell asteroidal materials to? Earth has plenty of water and hydrocarbons. Platinum sounds good but the average concentration in an iron-nickel asteroid is just hundreds of ppm. A lot of iron has to be separated from the Platinum Group Metals (PGMs) like irridium, palladium, ruthenium etc. For big mining operations big equipment is needed. What will it cost to rocket enough mining equipment to process millions of tons of asteroidal iron every year into LEO? Humans outside of the magnetosphere need about 11 tons of regolith shielding per square meter of hull and many other life support requirements. When it comes to humans to asteroids the answer is a great big NO.. Asteroid mining is going to depend on robots and AI. I have a lot of faith in robots and AI and look at the successful teleoperation of the Mars rovers from Earth. Robots could mine NEOs, But the problem still remains. Who are asteroid mining companies going to sell all that water and organic material to if there is no big industry including tourism in Earth orbit and on the Moon? Trillion dollar markets for propellant? Not without the Moon.

I focus on the Moon as a springboard to other destinations in the solar system including asteroids. It might take months for robotic freighters with ion drives to reach the Moon but humans can get there in high thrust chemical rockets in just 3 days time. They can refuel on the Moon with LOX and metallic fuels from regolith just about anywhere and with LH2 and LOX from polar ices. If you really want to keep the horse before the cart bootstrapping lunar industry comes before asteroid mining. Before that we need cheap access to LEO. I have high hopes for the Skylon. A single stage to LEO and back spaceplane is needed for tourism and tourism is the only thing that will create a trillion dollar market for asteroidal water and organics.. Communication satellites just don't need that much propellant for station keeping. The other thing that would make space profitable and involve a lot of transportation is Space Based Solar Power (SBSP)..

Without going into exact figures, it can be safely stated that providing propellant for a space tourism industry that moves millions of people to the Moon and back every year will require the mining of millions of tons of asteroidal material every year. Mining millions of tons of asteroidal material every year will require some heavy equipment, so i see the use of lunar materials to build the robotic asteroid mining ships. Since most asteroids are tumbling in 3 dimensions we need to work on ways to stabilize asteroids and that problem has not been solved.. If mining equipment can be sturdily anchored on an asteroid the motion might not matter much. So I don't agree with all this talk of asteroids or Mars being "easier" than the Moon just because delta V requirements are lower in some cases.

Traveling to the Moon

It takes quite a lot of dV to land on the surface of the Moon and return to Earth even with aerobraking. This only matters if all propellant comes from Earth. There is propellant on the Moon. LOX and metals can be gotten from regolith almost anywhere and there is water ice and more in polar craters. It only takes 3.2 km/sec to go from LEO to LLO and about 0.8 km/s to brake into LLO. It takes a dV of 1.6 km/s to land and another 1.6 km/s to return to LLO and 0.8 km/s to rocket back Earth with aerobraking. Ascent from the Moon and return to Earth, 1.6 + 0.8 =2.4 This can all be fueled from the Moon. With tankers or mass drivers and a station in LLO or at L1 the fuel for 1.6 km/s descent can also come from the Moon. So a ship in LEO only needs enough propellant for a dV of 4.0 km/sec and can get the rest from the Moon. Otherwise total dV from LEO to lunar surface is 3.2+ 0.8 +1.6 = 5.6 km/s And to come home too the total dV would be 5.6+ 1.6+0.8 = 8 km/sec It takes less dV to reach Mars and aerobrake or reach some asteroids, but time becomes a major factor when talking about Mars

or NEOs. With propellant from the Moon the problem of propellant for getting dV is lessened greatly A dV of 4.0 km/s is about that which is claimed for many NEOs. .

Challenging Assumptions

It seems desirable to use asteroids to supply propellant to ships in LEO instead of rocketing it up from Earth. The assumption is that this will be more economical. If lunar polar ices are mined it should be possible to supply water for hydrogen and oxygen to LEO by launching water tanks with mass drivers, collecting them at L5 or in lunar orbit, and using ion drives to move the tanks down to LEO. Could propellant from the Moon be as cheap or cheaper than propellant from NEOs? This is one of the many unknowns encountered when trying to envision the space future. We work based on assumptions, like mass drivers will be cheaper than rockets and asteroidal materials will be cheap to access because they are already in space and don't have to be launched from the bottom of a gravity well. In the future, many of our assumptions could be challenged by new technology like fusion rocket propulsion.

The Moon exists at the bottom of a shallow gravity well only 1/21 as deep as Earth's and because it has no atmosphere mass drivers and cheap electricity from solar panels can be used to launch lunar materials into space instead of rockets. Again, it is assumed that this will be more economical. Rockets are complex, costly and temperamental pieces of machinery. Reusing rockets incurs turn around costs. Launching millions of tons of material from the Moon into space with mass drivers instead of rockets seems like a far better proposition. The only barrier is that a large capital outlay is needed to construct the infrastructure on the Moon to do this.

Manned rockets that operate between the lunar surface and lunar orbit can use lunar propellant. It still seems that asteroids could supply LEO with propellant simply because they are already in space and not at the bottom of any significant gravity well at all. Asteroids can supply H_2O therefore hydrogen and oxygen, silicon to make silane SiH_4, carbon, nitrogen, and spent rock that has all the valuable elements roasted out that can then be used for mass driver reaction mass.

Mass Driver Propulsion

Propelling space freighters and tankers with mass drivers is worth considering. Exhaust V = Isp*9.8 km/s A 1000 second drive has an exhaust V of 9800 m/s Nuclear thermal rockets with hydrogen can do that but what about a mass driver? an 1800 G mass driver has an acceleration of 17,640 m/s^2 9800/17,640 = 0.555555 seconds Since s = 0.5 (17,640) (0.55555)^2 = 2,722 meters That's a long bulky mass driver.

A 450 second drive, equal to LH2 and LOX, has an exhaust V of 4,410 m/s 4,410/17,640 = 0.25 seconds s=0.5(17640)(0.25)^2 = 551 meters That seems like a reasonable mass driver. Crushed rock that has all its volatile elements roasted out is cheap and if we don't use it to propel tankers and freighters back to LEO and cis-lunar space it is just going to pile up uselessly.

Electric propulsion requires a lot of energy and it takes time for solar panels to charge capacitors then launch a mass with a mass driver. Ion drives accelerate slowly to terminal velocity not just because they have low thrusts but because they use a lot of energy to eject their reaction mass. If one determines the propellant mass for an ion drive given a certain dV and calculates the amount of energy in joules to exhaust that stuff, it is found that either enormous power plants are needed or extended lengths of time are needed to energize reaction mass.

You can figure out the propellant mass by using the rocket equation or go here: Rocket Equation Calculato Then you use KE = 0.5 mV^2 with V being the exhaust V and m the total propellant mass to

Figure out how much energy you need to eject all that stuff and since mass drivers are like electric motors figure about 90% efficiency and you can determine how much total energy you need. Divide that by the power of your solar panels and get the amount of time to deliver all that energy for ejecting reaction mass. 1 joule = 1 watt-second

Using the calculator i find that a 1,000,000 kg ship will need 1,500,000 kg reaction mass for a 4000 m/s trip back from an asteroid with mass driver propulsion at 450 seconds specific impulse.... 0.5(1500000)(4,410)^2 = 1.46 E 13 joules

At 90% efficiency a total of 1.62 E13 joules is needed.. That divided by 10 MWe, 1,620,675 seconds or 450 hours or 18.76 days.....If we can't wait about two and a half weeks to get our ship on course for a multi-month long voyage back to LEO we are being impatient.

10MWe with 1kWe/kg stretched lens array exotic solar panels is 10,000 kg and the ship amasses a million kg. A 550 meter long mass driver will be rather massive, how much i do not know. If the solar panels are 40% efficient and insolation is 1350 watts/m^2 we need about 185,000 square meters or a square 136 meters by 136 meters...not impossible.....

Low Thrust and High Thrust

Electric drives take a long time, even mass drivers, to accelerate to desired velocity.. So we need LH2/LOX or SiH4/LOX to propell rockets out of LEO and thru the Van Allen Belts to minimize radiation exposure time and reach the Moon in 3 days. We don't want to waste these hard won propellants by burning them in rocket engines on space freighters or tankers to ship LH2, SiH4, LOX, C and N2 back to LEO and cis-lunar space. It would seem more sensible to use mass driver propelled space freighters and tankers with rock powder reaction mass and patiently take time accelerating and decelerating the space freighters and tankers. Since it will take weeks to perform maneuvers and months or years to fly to an NEO or return to Earth-Moon space it might be better to ship water through space and silicon or silicon dioxide instead of cryogens and convert then to silane and LOX back in Earth orbit.

I have no doubt that asteroids and the Moon could supply all the propellant needed for lunar tourism. We just need the robots to do the mining.

What about getting the asteroid mining ship out of LEO? We might use regolith from the Moon or slag left over from processing regolith at an orbital construction shack that builds SPS and habitat for reaction mass. Since the ship will be leaving LEO with no cargo it will be light and propelling it thus "easier." It goes to the asteroid and fills up with LH2 or SiH4 and LOX. Add some crushed rock stored in plastic bags and away it goes.

Big Questions

What will things actually cost??? We base a lot of assumptions on energy requirements, but energy will be free once we pay for our solar panels. What will it cost to build asteroid mining ships??? What will it cost to operate the mining and material processing robots and operate the freighters/tankers??? What will it cost to mine the Moon and extract materials and mass driver them into space, and what will it cost to process lunar materials in space and move those materials around????

Nobody knows. Until we have cheap access to LEO and more experience working and doing business on the Moon and in orbit investors will be unwilling to put up their money. In the meantime, progress in space relies on government action. If governments built infrastructure in space and sold propellant and services to private space companies great things might happen.

Moving Entire Asteroids? NO!

If you found gold on an island you wouldn't move the whole island. You would work on the island and just haul the ore or the gold. Carbonaceous asteroids are 3 to 22% water.....Say we found a million ton asteroid that was 22% water...that would be 220,000 tons of H2O....Earlier i determined that a mass ratio of about 2.5 to 1 would be needed for a 4000 m/s dV with a mass driver engine Isp 450 seconds......therefore, moving 200,000 tons of water with a 20,000 ton space tanker requires 330,000 tons of reaction mass. A total of 530,000 tons of stuff comes from the asteroid. If we want to move the whole asteroid back to Earth-Moon space with a 450 sec. mass driver we have to use 600,000 tons for reaction mass and only 400,000 tons is left by the time we get back home. That means we throw most of the asteroid away and get only 88,000 tons of water....unless we dig up and grind up the entire asteroid out in deep space and roast out all the water and organics.....but then we have a pile of powdered rock instead of a whole solid asteroid....and many asteroids might not be so solid...they could be rubble piles. Why haul all that slag back to Earth-Moon space???? It makes more sense to extract the valuable materials and leave the chaffe or gangue (the miner's term) behind in solar orbit. Moving the whole asteroid is wasteful. Getting it closer to Earth doesn't make it any "easier" for robots to mine.

So we need robotic cargo ships and robotic mining machines. Chances are they will have masses more like 200 to 2000 tons and haul 2,000 to 20,000 tons of water at a time. The asteroid derived propellant industry would start off small and work its way up to something comparable to the terrestrial petroleum industry today. It will take a lot of time to mine up and process an entire asteroid the size of a mountain. I doubt that a 20,000 tons mining ship or even a mere 2,000 or 200 ton ship would be built of Earth launched materials. It would probably be built of lunar materials after we bootstrap industrial settlements on the Moon and launch several hundred thousand to millions of tons of materials into space every year. Without the Moon and Earth orbital industry there is no market for asteroid water and organic material so the Moon should be industrialized first. The logical sequence of events is:

1. Cheap access to LEO with reusable space planes and rockets.
2. LEO fuel depots.
3. Solar electric tugs for moving cargo to the Moon and even Mars.
4. Possibly a space station at L1 |
5. Bootstrapping lunar industry and constructing superconducting mass drivers
6. Building solar power satellites, asteroid mining ships and heavy asteroid mining and processing equipment with lunar materials
7. Using asteroidal water to fuel spaceships that haul millions of tourists to and from the Moon every year
8. Using asteroid water to fuel ships to Mars and other destinations in the solar system with as many space settlers as there are who can afford to emigrate.

The Unpredictable

This whole scenario could be up ended by advanced technology. Fusion rockets might not have enough thrust from their plasma exhausts to climb out of Earth's gravity well to reach LEO, but if they are constructed in LEO they could have enough thrust to dash through the Van Allen Belts and exhaust velocities so high that they use very little reaction mass. Millions of tons of water or silane and LOX would not be needed every year to fuel lunar tourism and colony ships to Mars.

Despinning an asteroid would be difficult if not impractical, but we might find asteroids tumbling so slowly that despinning is possible.

Mining solid metal asteroids will be lots tougher than mining stony carbonaceous asteroids. The nuts and bolts of metallic asteroid mining are not clear. Some have proposed using CO gas to separate the iron and nickel and get the PGMs present at a few hundred ppm. We could focus solar rays on a metallic asteroid with a huge reflector and vaporize it but the tumbling might make it impractical to keep the rays focused on one spot long enough to vaporize the metal and then how do you collect the vapors?? Vaporized iron loses its magnetism. Perhaps if it ionizes...or we ionize it with electron beams we could collect the vapor with charged devices of some sort. Lasers???

All this enthusiasm that has been drummed up because it takes less dV to reach some NEOs or Mars than the Moon is misleading. There's much more to the whole picture. Once we have a bootstrapping base or bases plural on the Moon there won't be much propellant cost to reach the Moon, and that's what this talk about dV is really about. Less dV means less propellant and supposedly propellant is expensive to rocket up to LEO, but once your are tapping propellant on the Moon things are much "easier." Anyhow, by using polar ices or metallic fuels and LOX from regolith anywhere on the Moon you don't need to haul propellant for landers from LEO to the Moon and you can even launch propellant with mass drivers, collect it in LLO, and use SEP tugs to take it down to LEO...some have even suggested mass driver launch strt to LEO and aerobraking.....Then there is all this talk about a kilometer wide asteroid having more PGMs than have ever been mined on Earth....but that asteroid consists of about a billion cubic meters of iron and nickel at about 7.7 tons per cubic meter....that's a lot of mass to deal with even in weightless conditions....and the enregy required to process it with CO gas or a mass spectrometer like device such as Dr. Schubert's All Isotope Separator will be huge....Details make or break a project. While we could mine up a stony asteroid, crush up the rock, roast out the volatiles with solar heated steam, CO or CO2 gas, then use the spent rock powder for reaction mass in mass drivers or quench guns for space freighter propulsion, turning solid iron into reaction mass won't be so easy, unless we have some real good lasers that can cut the stuff up like butter.....but lasers have been around for over 50 years and we don't have anything like that yet. I am not saying asteroid mining is impossible. I am saying it is not easy. Metallic asteroids don't offer much to work with besides iron and nickel. Stony asteroids offer oxygen, silicon, iron, magnesium, lesser amounts of calcium and aluminum, organics and water.....The Moon offers all that including titanium and richer sources of Al and Ca, but not much in the way of organics unless we find cometary ammonia and carbon compounds in the polar ices. If low mass fusion reactors become practical the whole picture changes. The trillion dollar market for propellant disappears because fusion rockets don't need a lot of reaction mass....SBSP is replaced with helium 3 mining so there isn't much launching of lunar materials into space....so who knows????

Thomas Jefferson thought it would take 500 years to settle the entirety of North America. He didn't foresee the steam locomotive. Fusion propulsion could open up the entire solar system and some people think it could even make interstellar travel possible. The future will tell. ##

Are these rocks truly “blue” or not?

Above: Are these rocks on Mars really blue? If they are, they are sure to be a popular collectible for Martian pioneers, but may be protected if they are rare. If the blue color is an artifact of the camera that took this picture, perhaps we can create eyeglasses that will let us see “blue rocks” everywhere – a welcome relief from the otherwise monochrome landscapes of the “Red” Planet. Note also the somewhat “blueish” background.

And yes, **the Martian sky will be noticeably less bright than ours.** Mars gets only about one half the sunlight as we are used to enjoying here on Earth.

In OUTBOUND issue #1, we wrote about the desirability of eyeglasses which would exaggerate color hues either side of the predominant rusty tones, making Marsscapes “prettier” and more interesting!