"Towards an Earth-Moon Economy - Developing Off-Planet Resources"

Mars ~~Moon~~ Miners' Manifesto

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Mars Theme Articles - MMM Years 1 - 10

July 2009 – MMMC Mars

Introducing the MMM Classics "Theme" Series

Over the past few years, we have been collecting all the non-time sensitive material from previous issues, reediting, re-illustrating, and republishing this material in PDF file collections, one per publication year. Currently, the MMM Classics cover publication years 1-20: MMM #s 1-200, December 1986 thru November 2006..

This July, we are introducing the MMM Classic Theme Series, collecting all the non-time sensitive material on specific themes, starting with Mars. The theme series will cover key topics as well as destinations, and thus be a valuable reference on favorite MMM topics.

Mars may seem an unusual favorite theme for a newsletter focused on the lunar frontier. But the reasons behind this coverage are several and clear.

The Editor has had a long fascination with Mars, beginning before he became even more fascinated with the greater challenge of the Moon. It has become our conviction that neither the lunar or Martian frontier settlements can become truly viable without mutual trade support. It would be most favorable if both worlds developed apace, the Moon slightly ahead of Mars. Mars enthusiasts, afraid that investment in the Moon will delay the opening of Mars indefinitely, are quick to write off any benefits that a developing lunar frontier might bring to the opening of Mars. "Cutting off your nose to spite your face," as the saying goes.

MMM has had articles about opening the frontier, the various resources on Mars, etc. But we also talk realistically about the many obstacles, location, climate, etc. Mars will not be a walk in the Park, despite the beliefs of many fans. We need to know the obstacles and challenges if we are going to find ways to work around them, as we have always done before when spreading into new locations. Mars is no more undoable for us, than the shores of the frozen Arctic Ocean would have been to people living in Africa. The epic of man has been about learning to live with a different set of conditions and a different set of resources, in every new frontier. And in time, we have mastered every new frontier, learning how to make ourselves at home.

At every step there have been those not equal to the challenge. But some were; that is all that has ever mattered. The human epic will continue. Beyond the lunar horizons, Mars is very much in our field of view. Humans will settle in every place they can, within the Solar System, and someday, beyond. Of stardust we are, to the stars we shall return. **<PK>**

Some of the Many Topics Covered Below

MARS PHOBOS DEIMOS

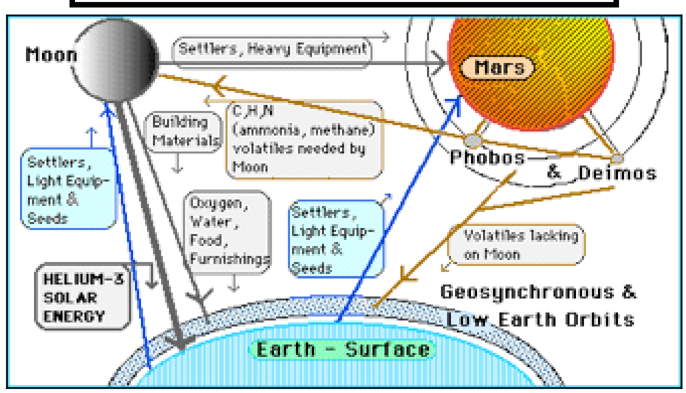
PAVONIS MONS

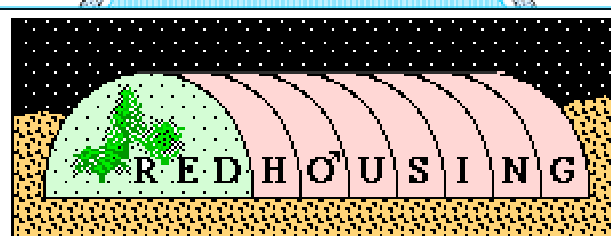
Mars: Option to Stay

MARS CALENDAR

Barsoom!

Frontier Republic of MARS





MMM #6 - JUNE 1987

ESSAYS IN "M"

by Peter Kokh kokhmmm@aol.com

M IS FOR MISSING VOLATILES: The Moon, as compared to our bountiful Earth, is very poor in elements with low boiling points, especially hydrogen (and thus water), nitrogen, and carbon (which is volatile in its usual form as carbon monoxide and/or carbon dioxide.) Other relatively volatile elements, like sodium and phosphorus, for examples, while present in usable and probably sufficient quantities, are less abundant than on Earth. This volatile depletion is one of the tests to which any theory of the Moon's origin must be put.

More importantly, this depletion sets constraints on what is economically possible on the Moon. Any Lunar civilization must import the bulk of the hydrogen (barring polar permashade ice fields*), carbon, and nitrogen it needs for biomass and life-support. Such a civilization must seek to find inorganic substitutes for non-life related uses to which these elements are put on Earth: wood, paper, plastics, coatings, adhesives, oil, and grease, etc.

[This was written eleven years before the exciting confirmation by the *Lunar Prospector* orbiting geo-chemical mapper, that such polar ice reserves do, in fact, exist. But even at "billions of tons," this is a very limited resource, which must be used wisely only for recyclable purposes. - Ed.]

M IS FOR METHANE & 'MMONIA: (*poetic license*) The easiest way to ship the missing volatiles is to combine them as methane (CH4) and ammonia (NH3) which are easier to liquefy and handle than liquid hydrogen, especially. But any excess needed hydrogen* would have to be imported in the pure form. (Some hydrochloric acid and hydrofluoric acid might be shipped to co-import any needed chlorine - to combine with Lunar sodium to make salt - and fluorine. Both may be needed to endow recycling ore extraction processes.)

To increase import efficiency to 100%, containers can be used which are made exclusively of elements the Moon needs to import. Such usable "tare" could be of metal, like copper, or of easily reduced solid hydrocarbons like polypropylene, (-CH(CH3)CH2-)^n.

* [Actually, of H, C, and N, Nitrogen will probably be in shortest supply in comparison to the amounts we will need, solely as a buffer gas used with oxygen for breathable "air". Nitrogen can be conserved by reducing the interior air pressure to half sea-level normal, but with the same amount or partial pressure of oxygen, reduced nitrogen accounting for all of the reduced air pressure. If indeed this shortage does turn out to be critical, it will be a strong incentive to keep ceilings low, Thus reducing the cubic volume of air needed per square foot of inhabited space. Goodbye visions of high-domed megastructures for the time being! - Editor.]

M IS FOR MINIMIZATION OF THE COST OF IMPORTING METHANE, AMMONIA, HYDROGEN, etc.

The Moon's top priority in its program to minimize the cost of its import burden will be to learn to replace (with native elements) or do without non-life-related usages of missing elements. Next in priority will be to develop sources of its import staples (hydrogen, methane, ammonia) that are less costly than "upporting" them from Earth. Any infant Lunar civilization MUST (or die!) open up other parts of the solar system as part and parcel of an integral and viable NTM economy (NTM = non-terrestrial materials). Mars is so close to having everything that is needed that may be a tendency of Martian Pioneers to be isolation-ist, not caring to open other space markets. If you want to guarantee widespread Solar System development, best to put your eggs in a basket that is strategically deficient! To have an interesting system-wide economy and commerce you need a system-wide community of interdependent places. Any extra-terrestrial game in which the name of the start square is not "LUNA" will be a dud. To those who say the Moon lacks the resources to support a civilization, we have a one word answer: Japan.

M IS FOR MANNED MISSIONS TO MARS AND ITS MOONS FROM THE MOON: If you want a mission which is not going to be an Apollo-type dead end, or so weight-restricted as to be a token effort you can do two things:

(1) Source as much of your throw weight as possible from the Moon. The spacecraft can be made largely from Lunar materials with their bootstrapping 20:1 advantage.

(2) Depart, fuel tanks topped off (at least Liquid Oxygen), from high on the shoulder of Earth's gravity well, for example from the L1 Lagrangian point about 40,000 Miles in from the Moon towards Earth.

While this would restrict departure to the period of the full moon to head you in the right direction with maximum velocity, the advantage will be so great that you could launch from L1 at several successive full moons on either side of the every-780-days window for the same energy cost as departure from LEO -- low Earth orbit -- at the the heart of the "window."

Looking down the road, manufacturing the building, construction, and mining equipment for use on Mars, Phobos, and Deimos will be a growth industry for the young Lunar settlements. Earth could not compete!

[The likelihood that, in many respects, mining and processing "regolith" on Phobos and Deimos will be very similar to operations on the Moon, makes such synergy all the more sensible.] MMM

MARS PHOBOS DEIMOS

By Peter Kokh kokhmmm@aol.com

Some several millions of years from now, Phobos is expected to spiral in towards Mars' equator, probably disintegrating under tidal stress to form a dark ring around the ocher planet. But for the near term, spirals with one end on Phobos or Deimos will be of freight out-ward to the Moon & LEO, and of freight and hope-ful settlers inward to a sandy Martian destiny.

Compared to Earth's Moon, of course, Phobos (12.4x14.3x17.4 miles) and Deimos (6x7.4x10 miles) are small "potatoes." Yet this works out to a surface area of 1,800 square miles for Phobos, 500 square miles for Deimos. [Compare with Rhode Island at 1212 sq. miles.] It has long been theorized that these moonlets are captured asteroids and indeed their reflectance spectra resemble that of carbonaceous chondrites, one of the major asteroid/ meteor-ite classes. This is what leads us to expect that they are rich in hydrogen, carbon, and nitrogen in one form or another as well as silicates and other oxides. The upcoming* Soviet PHOBOS mission will hopefully confirm this and set the stage for some very serious planning.

*[this mission ended in failure]

While it requires less energy for a round trip from LEO to the PhD twins than from LEO to the Moon, it is discreditingly ridicu-lous to suggest that LEO stations and depots get their liquid oxygen from the Martian moons rather than from the Moon. The Moon is handy all the time via a two or three day trip. The Martian moons are available only every twenty-five or so months and only via journeys from 6 months to two years long. Liquid hydrogen is quite another matter as the Moon cannot provide it (barring rich polar deposits**) and will need it even more than LEO. Hydrogen, methane, and ammonia can be processed on Deimos or Phobos and shipped to the Moon for perhaps a third of the cost of transporting them up the steep well from Earth -- that is, discounting initial capital investment.

**[*Lunar Prospector* did discover ice reserves on the Moon at both poles in 1998. But this is a limited resource that, in our opinion, should be reserved for recyclable uses in food production, biosphere maintenance, and industry for lunar settlements, and not blasted out the nozzle of rockets in a squandering one-time use. - PK]

Now often one reads that the real action will be in "Earth-crossing" and "Earth-approa-ching" asteroids and/or extinguished comets. The energy cost of round trips to these bodies will be even less than to PhD because one will not be infringing on even the shoulder of a planet-sized gravity well. But this expectation conveniently (naively?) overlooks one of the paradoxes of celestial mechanics: the more neighborly are the orbits of two bodies (e.g. Earth and asteroid 1982B) the less frequent are the synodic launch windows between them. With such bodies we are talking about opportunities decades apart, not just every 25-26 months! That is not to say that unique one-shot oppor-tunities shouldn't be seized. But for regular trade in volatiles, Phobos and Deimos have it all sewed up.

If LEO (low Earth orbit)-based comer-cial interest haven't already developed vola-tile processing on the "hurtling moons of Barsoom", any newborn Lunar settlement will be sure to do so as a matter of its own survival. An initial highly automated small crewed/ tended station on Phobos/Deimos would be coupled with an advance Mars' pre-exploration base that would continue Martian studies from orbit and via teleoperated rovers, planes, balloons, and dirigibles. As (and if) permanent habitation of this precociously legendary planet begins, the PhD outposts will grow into major transportation/ logistics nodes adding some home-grown wares to the heavy equipment being transshipped to Mars from the Moon. Logical items: plastics and pharmaceuticals, both hydrocarbon rich, to be shipped both to the Moon and down to the rustic settlements on the frigid deserts below.

But how could humans live on Phobos or Deimos, except in rotating tours of duty, with their physiology-wise negligible gravities? One possibility: a maglev train of habitat-cars on a steeply (89+ degrees) banked track within the lip of 3 mile wide Stickney crater on Phobos circling about every 114 seconds (307 mph) would simulate the 0.38g of Mars itself.

MARS!? - AS I SEE IT

by Peter Kokh kokhmmm@aol.com

For most of this century, there has been a steady retreat from the poignantly romantic portrait of a still living but dying Mars painted by Schiaparelli, Lowell above all, and Burroughs, and echoed even in Heinlein and Clarke. For many of us, the minority who pay attention to the News, this tenacious vision went "poof" with the first photos of the crater-pocked southern hemisphere of Mars returned by the fly-by of Mariner 4.

Rebounding, our spirits hitched a ride on a more complete set of pictures from the first orbiter, Mariner 9, which revealed tantalizing clues to a once-upon-a-time warmer and far wetter Mars. Was Mars in the midst of some temporary cyclic dormancy? Would the planet reawaken someday? Were there primitive but unique Martian life forms holding out in some incredibly long hibernation ready to be aroused from their long stasis by the kiss of some new epochal Spring?

Meanwhile the pictures steadily flowing in from the Viking orbiters revealed not so much a moon-like surface, as one as hauntingly beautiful and awe filling as our own southern Utah and northern Arizona. For millions raised on celluloid sequences of cowboys chasing and being chased up and down Monument Valley, Mars began to look like an unbelievably beautiful -- if barren -- setting in which to imagine all sorts of futures.

In our racial loneliness, most of us hoped that life would be found on Mars after all, in however humble a form. I remember well my own high excitement at the first teasing results of the pyrolitic release experiment. But when these suggestive indica-ions were not borne out out by other subsequent tests, I was filled with a crushing and abysmal disappoint-ment that lasted all of twenty seconds before giving way to a new euphoria: IF there is no native life on Mars, THEN Mars is "ours!" by default -- ready and waiting for our own life. Mars took on for me the raiment of a virgin world with mankind serving as the male reprod-uctive agency of Earth by which Gaian Earth-life would fertilize Mars and bring the long-waiting sterile world to the glory of planetary motherhood to which it could never aspire on its own -- no matter how long we left it alone.

Mars is still an easy #1 in any popularity poll of off-Earth destinations. Membership in the Planetary Society, which openly capitalized on the feline longevity of the Martian Romance, is ten times that of the National Space Society. To be sure, there are those so unforgiving for the shattered dreams of yore, and now so preoccupied with new alter-native space futures that they write sour-grapes articles such as "The Case Against Mars." Meanwhile, unapologetic "planetary chauvinists," cheerfully adopting this put-down label -- are not put off by such petulance.

As I weigh it, one of the greatest lessons learned at the feet of my mother, an amateur decorator among other things, is that any apparent disadvantage or "eye-sore" has the hidden potential, correctly approached, to become a unique asset, even a focal showpiece, around which to organize one's whole treatment. But you have to have the right frame of mind to discover the creative opportunities such "prob-lem" features pose. Evidently not all have such an outlook. The human "redecoration" of Mars will be no different. To arrive at the best, even stunning results, it will be neces-sary first to uncover, then to face honestly, the whole bag of tricks today's Mars has to roughen the path for various human dramas.

Those involved in the triennial CASE FOR MARS Conference in Boulder Colorado (# III will be held July 18-22, 1987) have their eyes wide open to such opportunity-laden problems; they are undauntedly brainstorming a human beachhead on those frozen rusty shores. It would be a mistake to dismiss them and their efforts. Yet despite their considerable progress in surmoun-ting obstacles prematurely thought to be show-stopping, is not yet cause to sound the rally call for a major national/international effort to put man on Mars in the adjacent future.

To begin with, the public at large is not yet finished with the romantic Marscapes of yesterday's speculations. Witness that no one -- save a few oddballs like me -- would volun-teer to settle Antarctica. Yet, in reality, Antarctica is not only just as awesomely beau-tiful and challenging as Mars, but it is warmer, has dense, breathable fresh air, is bounded by shores teeming with life and food, has an unlimited amount of pure -- not mineral saturated -- water, and even has inexhaustible energy in the steady, strong, reliable winds that blow incessantly from the pole out to the sea -- winds with much more force than those of Mars. Antarctica is a far, far friendlier, more forgiving, more welcoming "world" than Mars. If most people would unhesitatingly pick Mars, it is probably testimony to their flawed notions of what Mars is really like, rather than to some surprising hardiness responding to an unsurpassed challenge. To build public support, as the Planetary Society is doing, on the quicksand of public misinformation, is inviting a collapse from which it may be impossible to recover for generations.

A step by step approach to the humanization of Mars would begin with the establishment of a viably sized settlement on the Moon, followed up without delay by a complementary volatiles mining and processing facility on Phobos and / or Deimos, doing double duty as a forward base for the continued tele-exploration of Mars itself. Before then, of course, unmanned probes such as PHOBOS, VESTA, and the MARS OBSERVER, will have garnered much more knowledge of the Red Planet and its dark moons, and we will have a better idea of what is in store for us and how to tackle it. But this knowledge will remain sketchy, and Mars seems possessive of its secrets. We will still know far less about how to build, live, and survive on Mars than we already know about the Moon.

Nor will it be enough to have picked out "safe (for landing) yet geologically interesting" potential base sites. But from a forward base on Phobos or Deimos we could answer such important questions as: what minerals are where? How extensive is the permafrost layer? How thick is it? How deeply buried? How mineral-laden? How metal-poisoned? What soils can be processed to serve what functions? It certainly makes much more sense to have an indefinite series of sample returns to a lab a few thousand miles away on Phobos than a very limited one-shot sampling sent many millions of miles back to labs of Earth!

What about seismic activity? Are there any useful geothermal or areothermal hotspots? Are the soils in some areas more suitable as growing mediums than those elsewhere? How many differently sited settlements will be needed to provide all that is necessary for stable self-sufficiency? Will there be any logical export opportunities to pay for imports from the Moon and Earth? Someday, our homework done, the time will be ripe to set foot on this world of so many dreams -- not just to picnic and return home, but to stay. *Not now, not yet.*

But the cry "less ARMS, more MARS!" is strong and the Planetary Society may succeed in getting the nation to pick exploration (of Mars) over development (of non-terrestrial materials from the Moon, Phobos, etc.) as the reason-for-being for the space program in the coming decades.

Do we pout and sit on our hands? Do we play the role of good loser and pitch in? Or is there a third, much better option?

We must "second the motion" for Mars, aggressively pointing out that if the Mars Program funds (or co-funds?) a liquid oxygen processing facility on the Moon first, the Mars fleet will be able to fuel up more cheaply in LEO and then top off the tanks at L1 and thus be able to carry much more cargo to Mars. And the groundwork would be laid for follow-up missions.

[Here we clearly pre-stated the mission philosophy soon to be developed by Robert Zubrin, calling for in situ production of fuel for the return to Earth portion of any We also aggressively help by pushing the Mars Program to fund an advance party to Phobos (the prior launch window 780 days earlier) to set up a facility to process fuel for the return* and do continued remote/robotic research. Our prize? We get our foot in the door for free on both the Moon and Phobos and we benefit from free (to us) R&D for life-support systems and transportation hardware that we'll also need. Not compromise but the co-promising cross-fertilization of our dreams! MMM

In retrospect we might title this article:

MERGING EXPLORATION / DEVELOPMENT OF MARS / PHOBOS

MMM #16 - JUNE 1988

Frontiers Have Rough Edges

Commentary by Peter Kokh

[This was written with the Moon in mind, but applies to the Mars frontier as well]

A major theme running through many of the articles in the *MANIFESTO* has been this dual one:

- Settlers *can* become largely self-sufficient on a volatile-poor world like the Moon and in free-space oases initially dependent on Moon-sourced goods and raw materials
- This effort will involve widespread substitutions (and doing without, when substitutions can't be found) that will take some getting used to, as the pioneers wean themselves from an Earth-learned addiction to sophisticated organic materials so easily produced on the home world only to be casually used, often just once, sometimes not at all, and then just as casually thrown away. The transplantation of human society from Planet 3A to Planet 3B will involve definite sacrifices for the early trailblazers.

There may be many who, misguided by ill-thought-out science-fiction scenarios, look forward to life on the space frontier expecting that *there,* they will find the latest, the most advanced, the most sophisticated possible tech-nological culture. They would best be jolted out of such illusions and advised to stay home. For to tell the truth, for some decades after the opening of out-settlement, it will be *on Earth* that the highest, the most advanced, the most sophisticated material civilization will exist, at least in the more fortunate areas. In contrast, space frontier homestead scenes will *seem* insultingly drab, tedious, and harsh.

Even so, 17th and 18th Century Europeans who wanted the material best and most genteel that life had to offer remained in Europe. Even so, 19th Century East Coast Americans who wanted as comfortable and *materially* gratifying a life as possible remained in Boston, Philadelphia, Baltimore, and Charleston. The frontier is for those for whom other things are far more important than creature comforts and sophistication. It was so on the American and Australian frontiers, and will be on the frontiers of the future. Hardship is the stuff frontiers are made of!

Life in the new "outer Siberias" will be simpler, yes, simpler, even if forever dependent on high technology. But it will also be a more authentic and honest life with *more attention given to things that count.* There will be religiously rigorous recycling and careful accounting for everything.

The premium on art, craft, creativity, and ingenuity will be high and the opportunity to indulge in consumer itch-scratching shopping binges all but non-existent. There will be glory for both teamwork and individual contribution, but precious little room for unproductive self-involvement.

Despite the dependence on high technology, there will be a new partnership with nature in ark-sized biospheres, a heightened sensitivity to our symbiosis with plant and animal life; a realization that man and living nature thrive together or perish together.

Such prospects appeal to many environment- and ecology-sensitive persons in the Mother Earth movement, types that many of us space advocates customarily dismiss as not worth courting because these crusaders often seem to yearn for throwing out the technology-baby with its bath water. But this is constituency that can enrich us and provide a strength in alliance that we will never realize if we disdainfully go it alone.

If we love our cause, we'll set our egos aside and patiently woo these concerned and energetic individuals. Let's go together, those of us with the right stuff! The rough edges of this frontier are a rasp for personal and cultural baggage best left behind. -- Peter Kokh 5/88

MMM #18 - SEPTEMBER 1988

M.U.S.-c.l.e." a 2-part Acronym

You will have noticed the unusual way we spelled "muscle." For our strategy calls for the:

M.U.S. (Massive, Unitary, Simple) parts ***to be made by the settlement*** and the

C.L.E. (Complex, Lightweight, Electronic) components ***to be made on Earth*** to upport up the gravity well and be mated with the "MUS" subassembly on the Moon (or early space colony).

Here then is the logical formula for giving industrial muscle to the early settlement still too small to diversify into a maze of subcontracting establishments. It is a path that has been trod before. It plays on the strengths of the lunar situation and relies on the early basic industries: lunacrete, iron-steel, ceramic, and glass-glass composites (glax).

And not surprisingly, it is the path of lunar development that will produce the most in exports to LEO, GEO, L5 (?), and even Mars.

Importance of the M.U.S.-c.l.e. Plan for the Opening of Mars

Yes, Mars. That strangely romantic, sirenic world that so many are so impatient to get to *just once* even at the cost of perhaps never being able to return. It is possible to go direct to Mars from an LEO depot around Earth. The plan would send humans and cargo not needed till later separately. But if it is worth going to at all, it is worth having every advantage in our favor, including the capacity -- for the same total fuel cost -- of sending enough equipment to make a prolonged, even permanent stay possible as well as making follow-up trips economical enough to when they find out just how hostile a place withstand the inevitable public loss of interest Mars really is: that *Mars isn't Barsoom, after all!*

Using Made-on-Luna "M.U.S." Components to lower the cost of Missions to Mars

Back to our Mars expedition: think of the weight savings if only the basic core crew cabin (let the crew put up with the sardine-packing of "steerage" for the short trip out to the Moon on the shoulder of Earth's gravity well) and "C.L.E." cargo had to be boosted up from LEO. More spacious quarters in shell form (M.U.S.) and even the hulls of the Mars landers themselves could be added on at the lunar staging port (probably at the L1 Lagrangian point some 36,000 miles Earthward from the Moon). The crew would be highly motivated by the need for more space and could complete the assembly during the months-long journey out to the Red Planet. Give 'em something to do. The fuel savings would translate into more total cargo and, consequently, a much-enhanced chance of success on Mars.

After the Mars Frontier is "Opened"

If Mars were truly opened up for settlement, and it is in the Moon's interest that it should be developed as an alternative trading partner to Earth, then until Martian industry developed its own "muscle", there will be a strong market on Mars for made-on-Luna vehicle bodies and hulls, ready-made and portable shelters, and other items. It will be far less expensive for the new Martians to import items co-manufactured on Luna as opposed to those wholly made on Earth. Without this advantage, the Martian settlement effort will last only slightly longer than a snowball on Venus.

Further Contributions a Phobos-Deimos M.U.S.-c.l.e. Plan Could Make to Mars

Here we think of those items not needed by a Mars expedition until arrival in Mars orbit: aerobrake shields, parachutes, and landing skids / skis. This is in addition to fuel needed for descent and final braking. Ph.D. (Phobos/Deimos) could also make solar panels for Mars-orbiting communications satellites brought from Earth, etc.

Leveraging each new foothold in space
on the one before, we can go far!
-- Peter Kokh August 1988

PAVONIS MONS

Possibly the Most Strategic Mountain in the Solar Syestem

by Peter Kokh

Now that's some billing! We think of the great mountains in Earth's history. Mt. Olympus and Mt. Meru, homes for whole pantheons of gods; Hundreds, if not thousands, of mountains sacred to some tribal god; The great mountains of Judaism, Christianity, Islam, and Buddhism. In our day, the scattered mountaintops that have become the sacred preserve of great complexes of astronomical observatories: Kitt Peak, Cerro Tololo, and Mauna Kea above all. Then there are the holy mountains consecrated to paranoia: Cheyenne Mountain, for one.

When it comes to angry volcanic mountains, a whole string of names comes to the tongue as well: Vesuvius, Pele, St. Helens, Stromboli, and on and on. Earth has some pretty famous mountains.

Venus has mighty Maxwell Montes in Ishtar Terra, the northern continental Highland. And Mars' own Olympus Mons in sheer massiveness, 350 miles across the base, surely tops the list.

Pavonis Mons, "mountain of the peacock" (why it is so named, I have no clue), is the central peak of the three great shield volcanoes (Mauna Kea / Loa is a shield volcano, Earth's largest) of the Tharsis Ridge, flanked by Ascraeus Mons to the northeast and Arsia Mons to the southwest, with Olympus itself not too far away to the northwest. My map, from National Geographic, shows all four peaks topping out at an impressive 27 km! But that would be too much of a coincidence. Our knowledge of Martian altitudes is in dire need of refinement from future missions. But the exact figure is not going to change the picture.

What does matter is that Pavonis Mons pokes its head high above the densest portion of the thin Martian atmosphere (ours is 140 times more dense) smack on the equator. This suggests two possibilities.

1. THE site for a Launch Track

The more modest is that this mountain is the ideal textbook-perfect launch track site for payloads to Mars orbit, up the gently sloping west flank. At its estimated 87,000 feet above the average reference 'sea-level' altitude of Mars, all comparison to terrestrial equatorial mountains that might be considered for such duty (another article, we promise) simply ruptures. Long extinct (a billion years?), in all probability seismic
cally serene, glacier and avalanche-free, not subject to the typical torrential west slope rains of Earth's equatorial peaks: if launch tracks are your bag, then this is your mountain.

Other Location-Grounded Assets

It has other assets. Its equatorial position makes its caldera rim the best site on all Mars for an astronomical observatory complex accessing most of both north and south celestial hemispheres. While the seeing will not be as perfect as that offered *anywhere* on the Moon, it will certainly be far superior to the best available on Earth.

Advantages of being a Shield Volcano

Further, the flanks of Pavonis Mons offer two distinct advantages in common with the three other great Martian volcanoes as a site for major settlement.

- First, a basaltic composition with predictable composition. In contrast with the case for other areas of Mars, we know what we can build from on-site materials here, and here more then elsewhere, our Lunar experience will be most helpful.
- Second, if Mauna Loa / Mauna Kea are any indication, these giant Martian shield volcanoes should be laced with lavatubes of a size inter-mediate between terrestrial (a few meters wide, a few kilometers long) and lunar examples (hundreds of meters wide and as much as a hundred kilometers long): large enough to be useful for warehousing, industrial park sites, and initial as well as emergency shelter. This is an asset hard to overlook.

Other Neighborhood Assets

Just to the west of the escarpment which marks the base of Pavonis Mons is the large crater Ulysses. A settlement on the lower west flank of Pavonis Mons serving as the head for the launch track might then aptly and suggestively be christened *Ulysses Junction*.

It is hard to think of a name more pregnant with associations of cosmic wanderlust. Barring discovery of more suitable sites by the planned Mars Observer mission scheduled for a 1992 launch date (but threatened with postpone-ment), *Ulysses Junction* would be this writer's choice for the principal Martian settlement. That it is not smack in the middle of the most interesting geological terrain is not to the point. Sorry, Carl, but we didn't build Los Angeles on the rim of the Grand Canyon, much less in its bosom!

2. Anchor for a Space Elevator

The second possibility, a far out dream for Earth but at last a practical possibility on Mars, is a cableway elevator from the surface to synchronous orbit. Pavonis Mons would be the planet-side anchor. A Martian celestial elevator need only reach upward 10,500 miles to synchronous orbit (23,000 miles above Earth's surface) and fight a gravity only 38% as strong as Earth's. As a result, the requirements for mass and tensile strength ought to be an order of magnitude lower at least (but ask a mathematician or physicist). I personally doubt such a device will ever be built on / at Earth but confidently predict its realization for Mars. It may not be the first: toy-scale elevators may see service first on Ceres, Pallas, or Vesta. At any rate, such a development will only secure the role of *Ulysses Junction* as *the* Martian metropolis.

Deimos: The Elevator's other anchor

An elevator to where? Why to Deimos, of course! Conveniently, Deimos is the smaller of the two Martian moonlets, only 10x12x16 kilometers in size. Conveniently too, it currently orbits Mars only a little farther out (1900 miles) than synchronous orbit, making a circuit in 30 hours 21 minutes compared to Mars' 24 hours 37 minutes.

Implications for PhD Industrialization

This suggests that Deimos rather than Phobos be the main mining source of volatiles bound for Luna and that shipments be launched by mass-driver perpendicular (vertical) to Deimos' surface and in the direction of its orbit about Mars. In time, this steady action-reaction will bring Deimos manageable mass (relatively speaking to most other hypothetical subjects of planetary engineering) slowly spir-ling down to synchronous orbit where it could then be parked permanently directly above Pavonis Mons to become the gateway to and from Mars itself. Martians of the future will have a much easier (and cheaper) way to junket about the Solar System than Terrestrials. Let's put this in the 22nd century. (Such predictions are dangerous, but I won't be around to take the abuse from being wrong).

Phobos: Fly in the Ointment?

Whoa! Haven't we forgotten Phobos? It orbits between Deimos and Mars and would in short order intercept the cableway elevator and that would be that! Ho hum, details! There are a couple of approaches to this. The more ambitious and elegant would be to nudge Phobos outward a bit so that its orbital period would increase from the present 7 hours 39 minutes to 8 hours 12 minutes -- exactly one third the period of Mars and anything in synchronous orbit. This would involve moving it out from Mars only another 271 miles. But bear in mind that Phobos probably weighs about six or seven times as much as Deimos. Now if Phobos' orbital inclination with respect to Deimos was increased a teeny-weeny bit with the nodes carefully placed, it seems Phobos would always pass the elevator safely to one side, unless we've overlooked something, not that unlikely.

A less elegant and less ambitious approach would be to have some slack in the elevator so that it would have a slight bow in it that could be safely moved to the side when Phobos passed. At any rate, it may be a sought-after thrill to be on the elevator at just the right height when Phobos whizzed by at a rela-tive 3260 miles per hour! But we'll leave all these problems in the capable hands of 22nd century Martians.

So, go find yourself a good map of Mars (we have a good one from the Planetary Society incorporated into our space displays) and look up Pavonis Mons. Next get out the Yellow Pages and look for a real estate broker. This turf is going to be hot!

-- Peter Kokh September 1988

MMM #19 - OCTOBER 1988

Seizing the Reins of The MARS BANDWAGON

Commentary by Peter Kokh

To succeed at anything is *to create something that others can build upon.* There can be no other criterion of achieve-ment that is not self-delusory.

By deliberately choosing being first in a race as the measure of success, and spurning the Von Braun blueprint (a LEO space station for the assembly of reus-able Lunar ferries) in favor of a Lunar-orbit-and rendezvous mission profile, the Apollo strategists explicitly *chose to fail* by the only standard that would eventually matter.

They were politically conditioned to prefer ephemeral gratification of winning a ‘race’ and having momentary center stage. The opportunity to construct a transportation infrastructure that could serve con-tinued and sustained Lunar exploration and base maintenance was expediently shelved.

Many Mars enthusiasts would have us repeat this mistake. And on the other had, there are those in our Society who would have us concentrate on infrastructure alone, shutting their eyes to the absolute certainty, that without a declared goal, this infrastructure [NASA’s Space Station Freedom (freedom from purpose?)] will be missdesigned and missbuilt, and be inapro-priate as a stepping stone to *anywhere.*

It is common to portray our Society as the Moon party, the Planetary Society as the Mars party. We accept and encourage such a distinction at our peril. People on both sides of the Moon-Mars “debate” do the future of humankind in space a serious disservice by escalating this impatient, misbegotten polarization. What we sorely need is *a Moon-Mars consensus.*

Those who believe that we can build an autonomous spacefaring civilization based on volatile-poor Lunar resources alone are surely living in the land of Oz. Those who think that this Lunar resource shortfall can be made up by Earth-approa-ching asteroids (which owing to infrequent windows can hardly be more than sporadic targets of opportunity in the near term) ignore the laws of orbital mechanics. Without the additional regularly access-ible resources of Mars’ companions, Phobos and Deimos, and Earth-Moon economy will be doomed to inevitable collapse, however valiant and brilliant an effort is made to make a go of it -- a futile exercise.

Imagine an alternative solar system in which neither “Earth” nor “Mars” have natural satellites (even as Mercury and Venus do not) and in which there are no asteroids. Then try to construct a scen-ario by which a solar system ranging civi-lization might arise despite such handi-caps. Hard, isn’t it? Yes, we are blessed -- by chance or by design is not to the point. But to blueprint a spacefaring society while petulantly (yes! that is the right word!) ignoring those *assets handed us on silver platter* is patently stupid.

The Moon needs “Mars PhD” Mars needs Phobos, Deimos -- and the Moon. This inter-world trade economy will be the keystone of our future in space. Without this axis, we cannot economically fill Cislunar space with space colonies and solar power satellites. Without this backbone, we cannot realistically develop asteroidal and cometary resources. Without this anchoring, we cannot access the wealth of the Outer Solar System.

Those of us who want to postpone a “choice” between the Moon and Mars PhD are just as off track as those of us who want to rush such a “choice.” The truth is that in the end, *we will either have both or we will have neither.*

The one pragmatic strategy which alone promises us this Moon-Mars synergism is to court the considerable ranks of Mars advocates and convince them that what thev really want is not just a quickie release of pent-up curiosity in a one-shot exploratory picnic à la Apollo, but a sustained opening to Mars leading to permanent human presence there, to development and self-continuing settlement. Instead of pooh-poohing the chances for such a realization, we ought to be at the forefront - brainstorming the options.

Once Mars hopefuls are converted to the goal of making Mars a second homeworld for humanity, Lunar settlement and economic development will be assured, since it is the only way such an opening to Mars *can be sustained* in the face of certain and inevitable political and media disenchantment.

A Mars program worth pursuing includes the Moon and the Moon's needs. It enlists government financing of the infrastructure and technologies needed to open the Moon: deep space vehicles, closed loop life support systems, pocket-sized hospitals, etc. And then it leaves the way open to private enterprise and multi-national consortia to take it from there.

On the other hand, if the government is not occupied with Mars, i.e. if it is not benignly neglectful of the Moon, then no doubt the Moon will see activity, but *as a closed frontier* of a handful of government run Antarctic-style science stations. Unfortunately, there are many of us with sights so lowered that we would be content with so token a presence.

The Moon is the first, and most important (in terms of potential trade tonnage), part of the formula for an open space frontier. But it does not supply the whole underpinning. It is best that the attention of our government(s) be focused on the most all-encompassing, all-inclusive space vision, and that is the opening of a human frontier on Mars, and not mere limited manned exploration as the criterion of "success." Then well have it all: an open frontier that will eventually include the whole Solar System as the rightful range of our species.

It is time for our Society leadership and for our grass roots activists alike to awaken to these facts and seize the reins of the Mars Bandwagon, leading it where the Planetary Society has not the vision to venture. The challenge is great, and it is upon us now. If we avoid it, we fail. -- PK 9/88

[And drop the ball we did, making necessary the eventual formation of the independent Mars Society, whose founding we actively supported, giving Bob Zubrin a plenary session slot at ISDC 1998 to announce formation of the new Society.]

Settler Mars Quiz

QUESTIONS

1. On what planets (assuming a surface and a clear atmosphere) might you see a moon rise in the west and set in the east? (Hint. such moons must orbit faster than their planets rotate.)

2. "Hohmannliners" would be ships that plied between the planets on slow, minimum energy trajectories called Hohmann tran-sfer orbits. What is the risk in high energy "super Hohmann" spaceflights that could reach a planet faster?

3. Mars orbits the Sun just inside the Main Asteroid Belt. Why, especially when time is more important than price, will the Moon, not Mars nor Phobos/Deimos be the logical supply and resupply base for future "Belters?"

4. Where is the greatest known expanse of sand dunes in the Solar System?

5. In comparison with Earth, the Moon's mineral wealth is fairly homogeneously distributed. Will Mars be like the Moon in this respect, or will it have enriched deposits as does Earth?

6. What other geographic/geological features of economic import will attract Martian settlers?

7. Standing on one rim of the 150 mile wide Valles Marineris, the vast canyon complex on Mars, could one see the opposite rim?

ANSWERS

1. Mars [Phobos) and Jupiter (Metis and Adastrea)

2. If the speeding spaceship failed to decelerate on time, it would coast deeper into the outer Solar System, perhaps not to return to the inner system until after consumables had long been exhausted. But, just as assuredly, this risk will be accepted, once we have the propulsive power to attempt it..

3. First, Mars will have little need of asteroidal resources, whereas the Moon's need will be one of "do or die." Second, one commonly overlooked consequence of orbital mechanics is that the closer any two orbits lie in their periods, the less frequent are the Hohmann trajectory launch windows between them. To illustrate, windows open between Mars and Vesta every 47 months, between the Moon and Vesta, every 16.5 months; similarly there are opportunities every 38 months between Mars and Ceres, but suppliers need wait only 15.3 months for Moon-Ceres openings. The Lunar advantage is considerable. when fuel costs are secondary to timeliness. Yet science fiction writers and others com-monly assume that Mars will be "Asteroid Belt Central."

4. Surrounding the north polar cap of Mars, in the great circumpolar lowland basin known as Vastitas Borealis, the Northern Wastes, possibly the bed of an ancient ocean. Many features detected by Viking Orbiter cameras suggest this possi-bility, but only "ground-truth' sampling probes can confirm or disprove it.

5. The great unevenness with which Earth's mineral resources are distributed is the result of billions of years of plate tec-tonics involving continental plate drift, well-lubricated by an ample hydrosphere, the ocean. This process never occurred on the Moon, but may have operated sputter-ingly on Mars for a comparably brief period. It is an out-side chance that there are some enriched ore veins deposited by superheated water on a much smaller scale than on Earth. Searching for such veins may keep the hardiest prospectors busy, given the economic advantage that they would confer. The chaotic canyonlands at the western head of Valles Marineris, the Mariner Valleys, named Noctis Labyrin-thus, the Labyrinth of Night, might be one place to start looking.

6. Whichever way proves to be the easiest, simplest, and cheapest way to get water will determine a lot. We suspect exten-sive permafrost, ice-saturated ground, but do not know its extent, its nearness to the surface, its concentration (per-centage of ice to soil), or its saline and metal content. These will vary widely with the topography, and any permafrost will surely be easier to tap in some places than in others. If the main known water reservoir, the North Polar Cap, proves to be the most prac-tical source, detailed altimetry mapping of the lay of the land will deter-mine the easiest routes between the cap and the equatorial regions for ice-hauling trucks, and someday, for covered and heated canals or aquifers, hopefully with Lowellian names.

7. Yes, surprisingly, considering the tighter curvature and closer horizons of Mars compared to Earth. From one 5 mile high rim, you might see out as far as 145 miles along the valley floor, with the opposite rim standing two degrees above the horizon. But this incomparable may be totally "pinked out" by dust in the atmosphere, probably the usual situation.

MARS: OPTION TO STAY

By Peter Kokh

Perhaps most of our readers have read one or more speculative accounts of how Earth's first expedition to Mars will unfold -- the ships, the crew, the Mars shuttles and aerobrakes, the habitat and lab modules, the cross terrain vehicles, and the surface activities of scientific exploration. A half dozen books aimed at filling you in are already in the book stores. Since the *Case For Mars* Confer-ences began in 1981 in Boulder, Colorado, serious planning has become more and more elaborate and detailed. New options are being developed, less satisfactory ones discarded. Make no mistake. A whole lot of homework has already gone into Mars plan-ning and much more is underway.

All the scenarios currently being floated aim at a one-time scientific orgasm of activity -- and then we come home, probably never to return, once the public thrill with early results begins to wear thin. It goes without saying that all these people doing the careful planning will want to return to set up a permanent base. But once it finally sinks into the mass consciousness that even Antarctica is a friendlier place, political support will vanish and funding will vanish, *unless* ... unless we plan the very first Mars expedi-tion with a built-in OPTION TO STAY.

SCENARIO 1: Timeline 2010 (+10 -5)

√ A Complete Phobos Base:

A united (NSS, TPS, SSI, WSF, USSF, etc.) Mars front sells the government(s) on a beefed-up Mars Mission, successfully making the point that one deluxe mission will be cheaper than two economy expedi-tions and less dangerous. The govern-ment(s) have been convinced that a forward base on Phobos is necessary for success of the effort. This base will produce and stockpile fuels for the actual Mars landing and for the return trip to Earth and do the final preparatory Mars tele-science from its forward position.

Phobos (and/or Deimos) Base will teleoperate rovers on the Martian surface to do ground truth-checks to compare with data gathered by an armada of orbiting instruments monitoring the weather (moni-toring developing dust storms and dust devils), do landsat geochemical resource mapping (to help make wiser final site selections for a more productive mission), survey for permafrost and possible thermal hot spots and areas with abnormal radioac-tivity levels, do detailed high resolution altimetry and radar mapping (to get an idea of potential drainage patterns and routing choices), monitor a network of seismic penetrator stations listening for marsquakes, and sniff the atmosphere for recent and ongoing volcanic gas emissions. Surface rovers will also collect many samples for relatively cheap return to a Phobos lab only 3700 miles above rather than the long, time-consuming, and expensive return to the Earth-LEO labs many millions of miles away -- thus boosting the amount of soil samples that can be checked by many, many times. Phobos / Deimos could also teleoperate drone photo reconnaissance airplanes and dirigibles in the thin atmosphere below.

Meanwhile, Phobos Base will earn its keep by also processing volatiles (carbon, hydrogen, and nitrogen) in the form of methane (CH_4) and ammonia (NH_3) for back-shipment to thirsty Luna. There may well be a steady stream of *"tackliner"* cargo freighters -- container pods hauled to and fro most efficiently by great solar sails, accelerating slowly but persistently to give some measure of freedom from launch windows and building up caches of supplies from Mars orbit to be on hand when the sprinting human crews arrive.

Finally, Phobos Base could oversee the carefully plotted siting of parachute-landed robotic production plants on the Martian surface to stockpile nitrogen, oxygen, argon, carbon monoxide, water, methane, and ammonia -- all processed from the atmosphere -- to be ready for the base-to-be and handy for refueling the various planned cross-terrain expeditions. It might be possible, too, to drop automated facilities that would produce and store some fall-back food staples such as algae cakes. [*writen prior to Mars Direct*]

The Phobos Base would then have a joint mutually reinforcing mission: to vastly enhance the chances of success for a crewed Mars surface mission and to assist the economic bootstrapping of the early Moon Settlement so that it could manufac-ture and ship some items ["M.U.S.-c.l.e." in MMM #18] at considerably less expense than they could be sourced from Earth.

√ Mission Flight Profile:

A flexible flight profile is chosen which allows either a short stay (30 - 50 dates) and a longer interval before a 2nd base occupancy at the next opportunity (25 months between windows) or a longer stay (100 - 300 dates) with a shorter period of abandonment or, alternately, a shorter wait for anyone choosing to stay behind before reinforcements might (?) arrive on a follow-up mission.

√ A Full and Footloose Crew:

Only personnel without legal and moral obligations on Earth would be eligible, so that they could in fact exercise a free option to stay over as part of a base caretaker crew. The crew should come with talents beyond those strictly needed for the scientific success of the expedition. There should be a musical/performing talent, a journalist to produce a weekly base paper (*The Martian Chronicle,* of course), some with artistic and crafting talent, and so on.

√ Extra Marsbase Facilities:

1) <u>A Feasibility Lab</u>: the ivory tower pedantry of geophysics, geochemistry, and geology notwithstanding, we will not truly know Mars until we know how to provide for ourselves on that world from the resources it offers us. On-base air and fuel processing from the atmosphere is a step in the right direction. But we must also provide the base with a materials processing lab to develop easy-to-produce-and-use building and craft materials from the Martial soil. And such a facility must be staffed with appropriately talented and experienced individuals, and outfitted with the tools and equipment needed.

2) <u>An Experimental Farm</u>: Besides any agricultural unit (hydroponics or other) to help provide the crew with fresh food, we must have an experimental agricultural facility that works with the local soil and unaltered compressed Mars atmosphere (CO_2) to begin acculturating terrestrial plant species to a prospective new home. [We find the disconcertingly common belief that native Martian organisms could have survived three billion years of extremely hostile conditions incredulous! We also firmly believe that early Mars was not benign *long enough* to have allowed life to evolve in the first place!] Meanwhile, the food producing unit or farm should be generous enough and well-enough designed to provide a park-like retreat, no matter how small, for the crew. However hearty they may be, they will need the comforting reassurance that only being nestled by living nature can provide -- especially so for those considering staying behind.

3) <u>High Capacity Computer Facility</u>: The base should have first class computing power, not sized just to operate the base and handle incoming science data from the field teams, but ample enough to assist the Feasibility Lab and Experimental Farm, and with capacity to spare.

√ Incentives to Exercise the Option to Stay:

1) <u>Homework</u> galore for a sense of being needed here. There should be a

backup and supplemental agenda of field exploration for any Mars Science people staying on, with tasks sized for smaller crews, even individuals, closer to base, filling in the holes in the data from nearby targets of opportunity. Ongoing work tending both the regular and experimental farms, stockpiling a harvest of Mars-grown food for the next (hopefully) team from Earth -- would keep several people quite busy. An especially ambitious project would be locally grown cotton for the first made-on-Mars occasional wear, a sure morale booster worth the work and needed equipment.

2) Ongoing building and craft materials development with possible stockpiling of early production items for bootstrap base expansion when and if more people-power arrives. For respite, any personnel so involved could build up a cache of "Touch of Mars" craft items to make the place more homey, less sterile, less totally alien-derived. Such items might include ceramic or glass vases, flower pots, dishes and serving platters and mugs, jewelry, decorative tiles, and other furnishings accents to add a home-sweet-home ambiance to greet new arrivals.

3) Regular Phobos down-shipments of surprise package goodies made there or on the Moon. A continuous communications hookup for reassuring conversation with another nearby pocket of humanity without the isolation-reinforcing time delay (6-40 minutes from Earth / Moon) would be part of the "frosting" of a Phobos base (which, once begun, a Lunar outpost would attempt to maintain for its own needs even if Earth gave up on Mars). Regular newscasts on a "Marstime" schedule via relay satellite when necessary would give subtle security ("coming to you from radio XPHD in beautiful downtown Port Stickney. Here is today's Mars and Inner Belt news ...")

4) Other easy-to-provide low weight Seductively Martian Amenities: watches that tell Martian time and calendars that mark Martian dates [see next article] with Earth-dates in very fine print. A pre-prepared Martian sing-along book of well chosen *filk song* selections, perhaps even a specially composed Martian anthem: "Going Martian". An extra generous audio-visual library should be provided along with gaming and gym facilities.

5) A modest Retreat in the form of a detached cottage / station ("suburb") over the horizon where personnel could take turns getting away from the rest (downtown) whether for romantic privacy or just for a break, either relaxing, working on a hobby, or doing optional work.

And for those who go home, the great experience of their Martian sojourn will be the untranscendable high point of their lives, with everything to come being anti-climactic.

Those who stay will face unpredictable hardships (even the loneliest of deaths) and endless challenges (a brave new world that's never been touched) but also the possibility of even more rewarding experiences with yet higher highs. They may be the first ancestors of a new human world. Those choosing to stay on might mark the occasion by renaming the base (it will probably have been named so-and-so memorial station) something like (*Nos*) *Martiani* ((nohss) mahr-SHAH-nee, Latin for (we) Martians) for their choice will have made them the first.

SCENARIO II

In this scenario, the Moon joins the Earth's Mars effort in an enhancing function, providing facilities we (Luna) see as necessary for the Option To Stay but which the Earth government(s) do(es) not want to fund. This will include a module to house Lunar personnel to assemble and maintain the extra facilities in question. All this would be sent separately, at no freight penalty to the Terrestrials. It would include life support extras needed to allow a caretaker stayover, more built-in amenities, a building products feasibility lab, etc.

Such a Lunan effort might well be supported by Earth nations not invited to participate in the original mission. This might include China, India, Australia, Brazil, Korea, and other emerging giants. Such nations might provide equipment for the Moon-led mission enhancement effort that could not be provided by the Lunar settlement itself. Lunan personnel would be ready and able to take over the base on a tentative caretaker basis if no members of the principal expedition elect to stay.

How many personnel would be needed for scenarios I or II? Perhaps 40-50 with a quarter of them on Phobos/Deimos.

SCENARIO III

The Earth nation(s) that mount(s) the Mars expedition spurn(s) the "upstart" participation of the fledgling human community on the Moon. What can the early Lunar settlement do to promote its goals all the same? If the Lunans are advanced enough to set up their own Mars camp (the longer the first Mars landing is delayed, the less *un*likely this will be), they could have best effect by doing so on the basaltic (Lunar maria-like) slopes of the vast Tharsis bulge which includes the great Martian shield volcanoes [cf. MMM#18

"Pavonis Mons"]. An outpost at *"Ulysses Junction"* [ibid.] would concentrate not on Mars Science 101 (the geophysics, geology, geochemistry, and meteorology of Mars) but on Mars Science 102: learning to make building materials and furnishings for bootstrap base expansion Lunan style and from the familiar soils of this region. From here they might attempt to establish a visiting/trading relationship with the Earth-power(s) base which most likely will be sited off the Tharsis bulge but still in the same general area of Mars, so generously endowed with scenic wonders and geologically tempting targets.

If, on the other hand, Lunans are not prepared to participate uninvited on the planet's surface, but are involved in the staffing of the Phobos base, they might still be able to give logistical and moral (communications, see above) support. Hopefully, as Lunan relief crews arrive, the retiring Phobos staff would have the capacity to shuttle Mars-side staff to serve as a caretaker (or takeover) crew for the Mars Base when it is abandoned, perhaps permanently, by the nation(s) that erected it. Thus, even if men from Earth never returned, a Mars base, once built, might serve as the core of a growing community of transplanted Lunans, thanks to the Moon's need to maintain the Phobos Base, perhaps also built -- and abandoned -- by Earth.

MARS CALENDAR

By Peter Kokh

The Week and its Days

On Mars, it's always Tuesday (Tiw or Tiu was the Teutonic god of war identified with Mars of the Romans hence Tuesday is Mardi (French), Martes (Spanish), Martedi (Italian), Marti (Romanian) and Ares for the Greeks. For the Martian sol and day-night cycle is some 37 minutes 23 seconds longer than the day provided by Earth's rotation. Accordingly, if you inaugurated a Martian calendar with day one lined up -- day of the week for day of the week -- with Earth's calendar, by the middle of the 38th da, you'd be one full weekday behind Earth. And after some nine months, you'd be a full week behind. Fridays, Saturdays, and Sundays (to mention the more sacrosanct cows of sundry fundamentalisms) are not cosmic time markers, but arbitrary conventions that mean nothing, except by choice, even on Earth, much less beyond. A Martian calendar need pay no attention to what day of the week it is on Earth. To avoid confusion, future Martians should choose a different set of day names altogether.

"Seven" presents no problem -- it's arbitrary but extremely entrenched in human custom; Roman, French Revolutionary, and Russian Bolshevik attempts to institute eight, ten, and five days weeks respec-tively met with with most stubborn resis-tance. There are plenty of seven-sets besides ours which names the only seven solar system bodies (other than Earth) known from prehistoric times through 1780. There are seven major moons: Luna/the Moon (Earth), Io, Europa, Ganymede, Callisto (Jupiter), Titan (Saturn), Triton (Neptune). There are seven Greek vowels and seven musical notes in the diatonic scale (do, re, mi, fa, sol, la, ti). Colors can come in seven if the rainbow's five of red, orange, yellow, green, and blue are joined alternatively by violet and indigo, white and black, or purple and white (personal preference). Or perhaps a more Mars-like palette of red, ocher, rust, orange, pink, and salmon! Then there are seven spatial situations: one "here" and six "there"s -- fore, aft, right, left, up, and down (or alternately north, south, east, west, zenith, nadir). But why not go with seven different versions of Tuesday? All we need are seven totally different names for Mars from the Earth's many languages.

For month-like (circamestral) spans, local Martian sky rhythms do not give much guidance. It is eight hours from full Phobos to full Phobos and eleven hours from Phobosrise to Phobosrise; thirty-some hours from full Deimos to full Deimos and five days and an inconvenient fraction from Deimosrise to Deimosrise; meanwhile Phobos catches up with Deimos every ten and a fraction hours. So let's start with a clean slate.

Months

By our 24-hour reckoning, Mars takes 686.98 days to circuit the Sun. But a Mars calendar with its 2.6% longer days would only have a 668.6 dates. Conveniently, this is only 3.4 dates shy of 24 months of 28 dates (4 weeks exactly). A scheme with 23 months of 29 dates each would be a closer match (1.6 days too few) but would be awkward for dividing into the handy halves and quarters beloved of bookkeepers and tax collectors.

On the other hand, a month with four weeks exactly gives an enviably rational calendar in which every month begins on the same day of the week. As to the three or four dates that must be dropped every 24 months, I doubt that many would object to a "lost Monday" or its Martian equiva-lent here and there. As to the length, 28

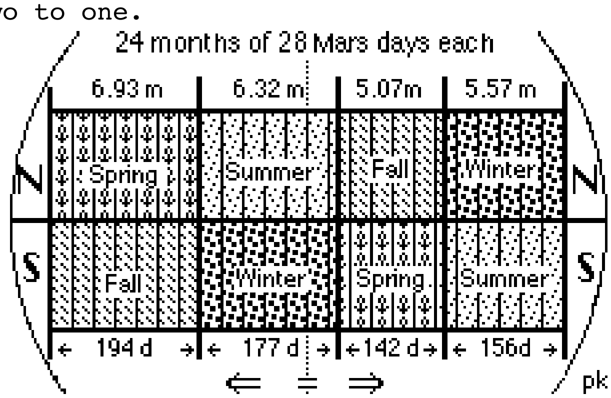
Mars-dates would approximate 28.75 Earth days, close to a leap February.

And names for the 24 months, one could, of course, propose twelve longer 56 date months, but I have chosen a rhythm more in keeping with tradition). Finding 24 names is not a problem either. Basing the names on the 24 letters of the Greek alphabet would be one solution. Another is taking the 12 constellations of the ecliptic (the Sun's apparent path through the celestial background) and either doubling them (Sagittarius I, Sagittarius II, Capricorn I, Capricorn II, etc.) or adding twelve other constellations from Mars celestial equator (different from ours, since Mars' poles -- similar tilt notwithstanding -- point in altogether different directions).

The "Half-Year" Plan

But again invoking custom and experience, I have a seemingly radical suggestion: divide the 668.6 date period of Mars' revolution about the Sun into two periods. One would count the 334.3 dates from perihelion (Mars closest to the Sun - paralleling the situation of our own January 1st) to aphelion (Mars furthest from the Sun.) The second would tally the dates from aphelion back to perihelion along Mars' comparatively eccentric path. Such alternating outbound and inbound periods, 343.5 Earth days long, would better embody our ingrained sense of "year" and serves as the marker for anniversaries, feasts and festivals, holidays and Holy Days.

In other words, whereas for Earthlings "year" and period of revolution about the Sun are taken to mean one and the same, I propose that elsewhere in the Solar System, we make a distinction in using these terms. "Year" would become a purely calendrical term, and "revolution" (or how about "Zodiac" or "Zode," for once around the Zodiac) an astronomical one. In the case of Mars, they would be related two to one.



For Martians of the future, all odd/outbound *years* would have similar patterns (roughly northern spring/summer, southern autumn/winter) and all even/inbound *years* would have similar patterns (northern autumn/winter, southern spring/summer.) Such a system of dual calendar years roughly commensurate with our cultural experience might be more palatable to those entrusted with leading their faithful in observance of a religious cadence of celebration, penance, and renewal.

To make such a system work, however, it would be better to have only one set of twelve month-names, perhaps with one suffix denoting odd outbound years, another even inbound years. That way, one would never mix up anniversaries and seasons. For a set of twelve month names to be repeated twice per orbit, constellation or zodiac names would not do at all. pairs of Greek letters might work. But again why not have twelve more different language versions of "Mars?" (That would make it always Tuesday, and always March, just in twelve different languages!)

Centuries

Spanning Earth's 100 year century would be 106.33 of these 6% shorter Martian years (Martenniums?). To avoid confusion, 100 Martian short-years could be called a Seculum [Latin for "age."].

The Epoch

Regardless of when we get to Mars, it would be convenient if the two epochs, Terrestrial and Martian, had a convenient point of convergence. I suggest that October 12, 2001, when Mars is at its firs perihelion in Earth's brand new millennium, be day one, year one on Mars. (If you prefer a Christocentric calibration of the epoch, that would make it the firs day of Martian year 2127, again following the split-year schema.

For some businessmen active on the interplanetary market and for that dwindling minority of Tory-minded Martian settlers who foster a fetish of having to know what time and day it is "really," a specialty calendar that noted the Earth date alongside the Mars date would be easy enough to provide. (It would have to tell the ever-advancing hour/minute time each Marsdate when the Earthdate began, Universal Time, Mars day being some 37+ minutes longer than ours) There are similar such calendars for those living on the interface of the Jewish and Western or Islamic and Western worlds.

Telling the Time of Day

Of course some Martian settlers may want to break all cultural bonds to Earth and manufacture analog clocks that use non-standard seconds, minutes, and hours - each 1.0275 times as long as on Earth. The penalty would be the need for wholesale translation of all scientific and technical works - a very stiff penalty for the sake of provincialism. Now if Mars were settled in only one time zone (15 degrees of longitude wide,) a digital watch could reset to 0:00:01 after each 8 hour we minute and 27 second "work shift." But scattered settlements and outposts in different areas, a system of time zones would be necessary and for the sake of synchronizing hours (think broadcasting schedules,) the hour would have to advance uniformly after every 61 minutes 33.5 seconds. Standard 60 minute hours could be used for all *elapsed time* determinations, and for scientific calculations. The 24 hour day is relatively unimportant in science. At any rate, time will fly on Tuesday's world also!

Telling Time on Phobos and Deimos

But what about those poor wretches working the mines on Deimos, or manning the Port of Mars Authority installations on Phobos? These two moonlets have their own day-night cycles. Fate, or something like it, is on the side of convenience here. Phobos first. Its day-night routine is just 20.6 minutes shy of an Earth-style 8 hour shift. Put three of these to a Phobos date (100 seconds shy of 23 hours) and thirty of these would be just 17 minutes shy of a standard 28 date Martian month. So while Phobos work details might use local time, at least they could synchronize their "months" with those of the rusty dusties down below. To avoid confusion, Phosobsdates could be lettered or counted down, or rely on some other telltale indicator.

On Deimos, however, the day-night cycle or sol is inconveniently long at 30 hours and 21 minutes, a difficult, but not impossible adjustment for the human system. Yet obligingly, 3/4 of this period would give us Phobos-like dates 22.77 hours long (4 dates per 3 periods.) The lighting patterns would repeat every 4th, 8th, 12th etc. dates (an 8 day week would work well for pattern repeat purposes.) And again, 30 such shorter dates would mesh well with the Martian 28-date month pace. In both cases, thanks to digital timekeeping, preserving a solar system wide standard second and minute, and even the hour, would be no problem at all. A digital watch can reset to zero at any odd pre-progammed sum of hours, minutes, and seconds. Such a watch could be devised to show the time alternately on Mars (specify time zone, please,) Phobos and Deimos. ***PK***

NOTE: The Author has since reworked these ideas to maturity. (1999} Read all about "**The MarsPulse Calendar**" online at:

www.lunar-reclamation.org/mars/marspulse_cal.html

NIMF

Nuclear rocket using Indigenous Martian Fuel

An Enabling Technology for Manned Mars Missions with Global Access in a Single Launch

Robert M. Zubrin

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ABSTRACT: This paper presents a preliminary examination of a novel concept for a Mars descent, ascent, and exploratory vehicle. Propulsion is provided by utilizing a nuclear thermal reactor to heat a propellant gas indigenous to Mars to form a high thrust rocket exhaust.Candidate propellants whose performance, materials, compatability, and ease of acquisition are examined include carbon dioxide, water, methane, nitrogen, carbon monoxide, and argon. Ballistic and winged supersonic vehicle configurations are discussed. The use of this method of propulsion potentially offers high payoff to a manned Mars mission both by sharply reducing the initial mission mass required in low Earth orbit, and by providing Mars explorers with greatly enhanced mobility in traveling about the planet through the use of a vehicle that can refuel itself each time it lands. utilizing the nuclear landing craft in combination with a hydrogen fueled nuclear thermal interplanetary vehicle and a heavy lift booster, it is possible to achieve a manned Mars mission in one launch.

INTRODUCTION: Interplanetary travel and colonization can be greatly facilitated if indigenous propellants can be used in place of those transported from Earth. Nuclear thermal rockets, which use a solid core fission reactor to heat a gaseous propellant, and which were successfully developed during the 1960s under the ROVER/NERVA programs as hydrogen fueled interplanetary transfer vehicles, offer significant promise in this regard, since, in principle, any gas at all can be made to perform to some extent. Here we present a preliminary examination of the potential implementation of such a concept in the context of manned Mars missions. This vehicle we term a NIMF: Nuclear rocket using Indigenous Martian Fuel.

[Body of Paper Condensed by MMM Editor]

Candidate Martian Propellants

The atmosphere of Mars consists of
95.0% carbon dioxide [CO_2]
2.7% nitrogen [N]
1.6% argon [A]
all of which are candidate fuels for NIMF. Water could also be used after harvesting ice or permafrost. Carbon monoxide [CO] and methane [CH_4] can be produced from the above atmospheric gases by processing.

Table 1: Ideal Specific Impulse of Martian Propellants

Temp °K	CO_2	H_2O	CH_4	CO/N_2	A
** 2800	283	370	606	253	165
3000	310	393	625	264	172
* 3200	337	418	644	274	178
3500	381	458	671	289	187

NB.** 2800 °K = safe operating temperature per extensive NERVA testing

* 3200 °K may eventually be attainable

Carbon Dioxide - composing 95% of the Martian atmosphere, can be obtained by pumping the air into a tank. At a typical ambient temperature of -40 °C, CO_2 liquifies at 10 ATM for an energy cost of just 84 kW hrs per metric ton. A NIMF engine produces over 1000 MW (thermal). If an electrical capacity of 1 MWe is built in as well, then the 2800 K, 40 metric ton, NIMF would be able to fuel itself for a flight into a high orbit in less than 14 hours! Liquid CO_2 has a density of 1.16 times that of water and is eminently storable under Martian conditions.

Since CO_2 is so readily acquired, it is a convenient fuel for multiple suborbital hops, allowing a Mars exploration mission to visit many sites (either as a ballistic hopper or as a supersonic winged aircraft. - Figures 1 & 2).

One drawback is that CO_2 (and water) would oxidize carbide elements at the high temperatures involved. Instead high temper--ature oxide elements, possibly coated uranium-thorium oxide, must be used, and such elements would probably be incompatible with the high Isp hydrogen fuel ideal for interplanetary usage.

Water: In the form of permafrost ice, water is commonly expected to be abundant, but it will require an operation of some complexity to harvest it. Once a Martian base is established, locally mined water could function as a near ideal fuel for both Earth return, near Mars, and beyond Mars operations. If a base on Phobos is used for a point of departure, a 3000 °K water propelled NIMF could fly to Earth, aerobrake into a loosely bound orbit, and return to Mars without refueling!

Methane: Per the table above, methane would be an excellent high Isp [specific impulse] fuel. It could be produced and stored under refrigeration at advanced surface stations (not suitable for early use or needs). Moreover, it is compatible with conventional NERVA carbide elements. An unresolved problem is that methane would dissociate at the high temperatures involved with free carbons causing coking problems. Experimentation is needed.

Nitrogen, carbon monoxide, and argon [see the table] are inferior to the much more readily available carbon dioxide. Further, they require about a hundred times as much energy to produce. However, they have the advantage of not reacting chemically with fuel or cladding materials compatible with hydrogen. Thus the same reactor which uses carbon monoxide for ascent to orbit could also use hydrogen with 950 Isp for interplanetary transfers.

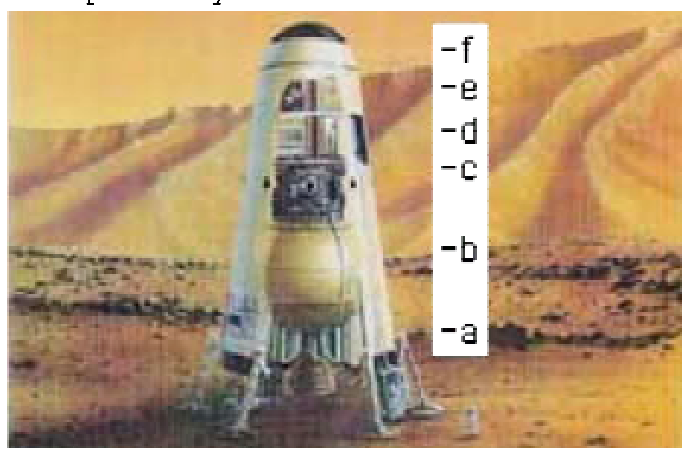

Figure 1: A NIMF ballistic vehicle on Mars (by Martin Marietta artist Robert Murray]

a. Nuclear engine surrounded by a coaxial fuel tank (when full, augments the solid lithium/tungsten shadow shield with liquid CO_2)
b. main spherical fuel tank
c. Machine deck with CO_2 intake pumps.
d. Habitation deck. e. Command deck.
f. Parachute (several) compartment.

Nb. The NIMF's fuselage acts as an aero-brake, with a lift/drag approaching unity.

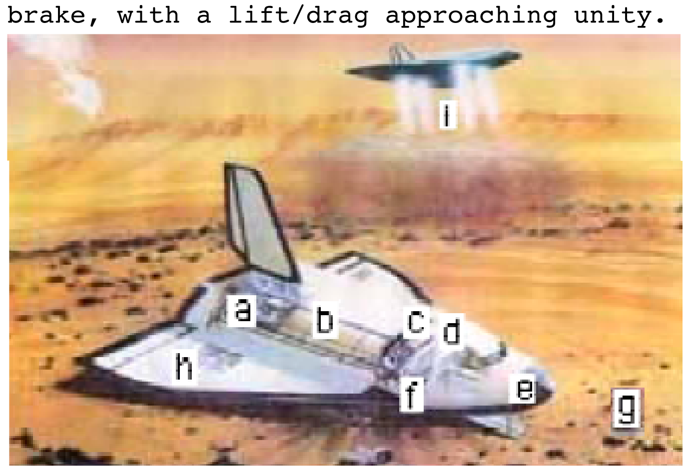

Figure 2: Winged NIMF rocketplane on Mars. (courtesy free lance artist Jeff Danelek)

a. Nuclear engine surrounded by coaxial four-pi liquid shield
b. The main tank forward of the reactor.
c. Machine compartment
d. Habitation compartment
e. Control deck.
f. Forward storage area with ramp
g. Electric rover charged by NIMF reactor
h. Delta shuttle-like wings for supersonic flight with lift/drag of 4 at Mach 4
i. 4 VTOL underslung rockets for Harrier-like landings/ascents from/to Mach 1

A NANNED NARS MISSION IN A SINGLE LAUNCH

Since the days of the Apollo program, NASA's thinking about manned planetary landings has been dominated by approaches based on an orbiting mother ship containing long term living quarters and a small landing craft, a fraction of which manages to ascend to orbit after a stay on the surface. With the advent of NIMF, such an approach is no longer necessary. In fact, since any mass landed upon Mars can be lifted back to orbit using readily available indigenous propellant, it becomes advantageous to abandon the concept of the orbiting mother ship altogether, and instead land the entire spacecraft living quarters on the planet's surface. That is, NIMF and interplanetary vessel are one.

Three alternative mission scenarios were examined. In each case, a 40 metric ton NIMF with a 3 person crew departs from a 300 km LEO orbit on a minimum energy trajectory to Mars, lands on Mars, hops around visiting various sites, ultimately returns to Earth via Hohmann transfer orbit.

Scenario I uses an orbital transfer vehicle (OTV) to propel NIMF out of LEO, and which is then expended. This is the cheapest option in terms of total fuel use. In the other two scenarios, the OTV accompanies NIMF to Mars and is stored in Mars orbit for the joint return. In **Scenario 2** both aerobrake at Mars, saving fuel while in **Scenario 3** the NERVA-OTV brakes via a retrofire to keep it out of the Martian atmosphere. In either variation, artificial gravity could be provided for the long interplanetary trips out and back by spinning the pair at opposite ends of a tether.

NIMF MANNED MARS MISSIONS: 3 SCENARIOS

(metric tons)	Scen.1	Scen.2	Scen.3
Mission Mass	73	100	145
Expended Mass	33	53	100

There are numerous missionarchitectures where an initial manned Mars Mission can be accomplished with a single launch of the STS-Z (125 MT to LEO) or ALS (100 MT to LEO) or even by a single Shuttle-C (80 MT to LEO). Furthermore, repeat missions (craft already in space, needing only refueling and reprovisioning) can be supported by a single shuttle, Titan IV upgrade, or STS-C launch. This contrasts with current NASA plans which would require from 700-1000 metric tons of propellant per mission, 6 or more STS-Z launches! Yet despite their enormous cost and complexity, such mission plans leave the explorers relatively impotent to accomplish much in the way of either exploration or development, as their cryogenic landing vehicle will necessarily restrict their visits to ne site, and they lack a substantial source of electric or thermal power i.e. little potential for human exploration of the Red Planet and none at all for sustaining a human presence there. NIMF will allow ready, repeated, and inexpensive access to Mars, opening up a new world to humans.

MERITS OF NIMF VS CHEMICAL (CO+O2) HOPPERS

In some respects, these two candidates for getting around Mars (Global Access) are equal. Both obtain a specific impulse in the 280-290 range. While neither engine is a developed technology today, the principles underlying both are well understood, and either could be developed given the appropriate development funds.

However, that's where the equivalence with the chemical option ends. The energy cost for producing CO and O2 from the atmosphere is more than one hundred times that for simply liquefying the given CO2. Worse yet for the chemical hopper, we not only have to pay an exorbitant premium for the fuel, but we have to pay for a ground-based nuclear reactor and a significant chemical engineering plant. That's a lot of infrastructure that NIMF doesn't need. The corresponding features are built into NIMF. If we go with the chemical option, global access will be delayed possibly for years, until the needed development is in place. With NIMF, such global access is an immediate capability.

Since NIMF can refuel itself for return trips, it can go as far one way as its fuel will allow, landing empty. In contrast, the chemical hopper must carry fuel for the return *and* extra first leg fuel to bring the return fuel along. By the same token, we can afford to build NIMF heavier, with a stronger frame that can carry more instruments and supplies, capable of extended forays.

The chemical hopper must be on target on its return trips, pay attention to boiloff, outgassing, and other potentially explosive and toxic leakage of its cryogenic fuels. Immune to all this, NIMF can recharge the fuel cells on land rovers it carries, not so the chemical hopper.

Highly versatile non-ballistic supersonic winged aircraft configurations are possible for NIMF which is less weight restricted. Because the NIMF propellant is the atmosphere itself, in-flight propellant acquisition systems are possible - not so for the chemical vehicle.

What about safety? NIMF carries a nuclear reactor (however 5 orders of magnitude less radioactive than a power reactor, and not capable of meltdown). This small radioactive inventory represents a small hazard compared to that presented by the chemical alternative to NIMF, which will be virtually a flying bomb, a lightly built structure filled to the gills with toxic gas and chemical high explosives.

OTHER EXOTIC MISSIONS FOR NIMF ALONE

- A winged automated NIMF condensing its CO2 from the air, could carry out a **Venus surface sample return**, collecting ground samples and low level aerial reconnaissance from every part of the planet before returning to orbit.
- A methane propelled NIMF could use **Titan as a base for repeat sallies to Saturn's moons**, returning to Earth with ground samples and low level observations from each one.
- A water fueled NIMF could **explore the Jovian system** from Callisto, Ganymede, and Europa.
- Water fueled NIMFs refueling on Ceres, the Trojans, even comets, could explore the Asteroid Belt, and the entire system including Pluto as well as comet sample returns. - [**RZ**/pk]

WANTED

By Peter Kokh

WANTED: Split personality types for Mars Expedition. Besides being willing and able to leave Earth, family, and friends behind for three years or more, must *for the trip out and back*, have a high tolerance for sensory deprivation and thrive on boring routine tasks; and, at the same time, *for the period spent on the surface,* must be thrill- and challenge positive, keenly attuned to external situations with all their unpredictability. If you are such a Jekyll-Hyde combination, please send your resume to:

- Mars Expedition Personnel Office
- Mars Training Camp
- Spitzbergen

For as long as the era of chemical rockets lasts, interplanetary journeys to Mars or the asteroids, will be long tedious affairs that will be very trying for the kind of people ideally suited for the kind of life that awaits them at their destinations. This presents us with a choice. We can either look for persons with such chimeric personality combinations as suggested above who will perform reasonably well under such diametrically opposite circumstances, *or* we can start now to plan ways to structure the times of transit to better fit the personality traits of those best cut out for the exploratory and/or rugged pioneer life on the untamed worlds of their destination.

The path of least effort, and a temptation to mission planners, is the former. Transit times will be filled with makework: solar-wind measurements and other astronomical chores that could either be done just as well from LEO, or if not, by robot probes. To this will be added routine periods of exercise and other monastic treats. Meanwhile, people better suited for the planetary surface stay itself, will be bypassed if they evidence any signs of being less content than pigs in a mud hole by such a diet of time-whittling.

We need to take a creative look at alternatives. First, we must recognize that the trip out and the trip home are radically different in the deep psychological challenges they present. Outbound, the crew will be filled with anticipation. Homebound, they may experience both anticlimactic letdown and an impatience to get back home.

The opportunities for damping these feelings with engrossing and meaningful activities are also diverse. In the article "M.U.S./c.l.e." [MMM #18, Sep. '88] we suggested that equipment manufactured on Earth for use on the Martian surface be disassembled (all parts tested and checked individual and in test assembly) to be put together in a Big Dumb Volume hold manufactured for the expedition in Lunar Outposts. The crew would be highly motivated to put everything together right. This opportunity will predictably be seen as risky business by some who may favor keeping Mars-bound crews busy performing safer make-work.

Surface expedition concluded, the crew would be similarly motivated to do preliminary chemical and physical analysis of samples being returned to Earth, along with some building materials processing experiments. NASA, however, may forbid them to touch the samples, not trusting them to handle the precious cargo and possibly invalidate intended research by more expert investigators in better equipped Earthside labs.

In both cases, there is probably a point of compromise between NASA's natural paternalistic prudence and the not unimportant needs of the explorers-en-route. For example, ultra-critical equipment can be shipped preassembled, with less sensitive equipment and backup equipment shipped "KD" (knocked-down) for assembly en route.

For the Earth-return, a similar division could be made. Surface samples could be separated into two quota por--tions, those held safe and untouched for labs on Earth/LEO, and those on which preliminary analysis and experimentation can proceed en route; trained geologists, chemists, and other scientists will be essential to the crew. To deny them "first rights" can only sow and nourish a festering resentment. Such avoidable psychological compost heaps should not be discounted as threats to the overall success of the mission.

In the overall spirit and atmosphere aboard the return crew vessel is positive, there will be other time-filling things to do. Debriefings and reports while experiences are fresh can be followed by round table discussions of how the success of a follow-up mission could be enhanced (new equipment, tools, lap facilities, housing etc.; better training; additional talents represented in the crew mix, etc.) Sensory and other impressions can be set to canvas or disk by those on board of artistic, poetic, or philosophical bent.

So much for generalities. Undetermined at this time, but absolutely relevant to the matter we are considering, is whether the voyagers will enjoy the amenities or artificial gravity for the long coast out and back. One gets the feeling that provision of at least fractional weight poses engineering challenges that neither Intercosmos nor NASA are eager to tackle. So what if the astronauts or cosmonauts can survive such long periods of zero-G without irreparable harm! The uncllengable reality that the crew of a zero-G ship will arrive at Mars in a physical shape unequal to the demanding tasks at hand in the very limited time frame provided, should be more than enough to convince mission planners to err on the side of patience. One wonders whom they are kidding!

Marsweight, 38% Earth-normal, can be provided by a simple tether arrangement with crew pods at one end and equipment not needed before arrival at the other. Artificial gravity can also be provided more elaborately by a fixed structure, for example by a conjoining for the Marsbound craft as in the Case for Mars I studies.

Experiments with tether-provided artificial gravity could begin soon using the Shuttle and an External Tank brought to orbit with it. We have yet to do an EVA in an artificial gravity environment! An astronaut would have to remain tethered and would share the angular momentum that obtained at the exit lock. It would be tricky stuff at first, fraught with perils that could nonetheless become routine, even as driving in heavy traffic or flying in formation. Appropri-ate maneuvers and cautious could become second nature. There will be mis-moves but careful provision could minimize serious accidents.

The point to be made here is that, to NASA's abject horror, no doubt, there is a very real opportunity for totally new tethered-EVA sports outside rotating structures. By shortening a tether to the hub, one would advance on the structure; by paying it out one would fall behind - simple conservation of angular momentum. Using such maneuvers in tag matches might be risky, but rally-type events tin which one faced the clock, one at a time, to land first on a forward perch or tag ring, then on one to the rear, before returning 'home', all b manipulating the effective length of the tether, could provide healthy, adrenalin-racing sport. This could be welcome stuff to a crew chosen to be optimally tuned to the pace of activity of the Mars surface part of the expedition. When such sport is embraced, either on the sly or with reluctant official consent, we'll have come a long way towards making the spacelanes home. [PK]

MARS CALENDAR

FI$CAL POSTSCRIPT

[to "Mars Calendar" MMM #19 October 1988]
by Peter Kokh

In the previous article, we suggested that the 668.6 Martian date (24 hr 37 min 23 sec) long orbital period of Mars was an inconveniently long peg on which to hang anniversaries and the rotation of holidays, holy days, and other recurring observances. Halving this period would provide more comfortable 334.3 Mars date ceremonial cycles 343.4 Earth days long.

All that would be required would be the introduction of a distinction of terms. The "demi" period described above could be called a "Marscal" or an "Ennium"; the full orbital period, a "Zodian" i.e. once around the Zodiac, or something to that effect.

Reaction to these suggestions was generally positive. But we also heard from Tories (i.e. those unable to leave the mother culture behind) who insisted that for practical business reasons, the standard 24 hour Earth day and 365/6 day year would prevail throughout the Solar System, that when the Sun rises or sets on Mars is irrelevant. (We had suggested that Martian Law protect such people, allowing them to hide "Earth-style" calendars under their pillows without fear of search & seizure.)

To fairly address the interests of business in this matter, let's take another look, this time from the vantage point of the business cycle: the Fiscal Year. On Earth, a "fiscal year" is any twelve month period, not necessarily coincident with the calendar year that provides a convenient accounting cycle for a particular business. By common practice, any business subject to regular busy and slow seasons, closes the books, completing the accounting cycle, at the end of its most active season. Businesses catering primarily to summer tourists might close their fiscal year on Sept. 30th, beginning the next on October 1st. Ski resorts might pick March 31st as the end of their cycle; Department stores January 31st, etc. At any rate, it is the seasons or consumer buying cycles or inventory cycles - the length of the fiscal year on Earth remaining the same - the 365/6 days of the civil calendar.

On Mars, those businesses involving transactions principally among the settler population and whose ups and downs are significantly affected by the passage of the long Martian seasons, will only be able to introduce real accounting regularity (fiscal comparability of one business cycle to the next) by adopting the full 668/9 date length of the Martian "year" or "zodian," with cycle opening and closing dates appropriate to business type.

It is reasonable to expect at least some businesses to fall in this category. But we might also expect services and manufacturing businesses whose ups and downs will be pegged rather to the civil "demi-calendar" of 334/5 Mars dates.

But then what about the Export-Import Houses trading with Earth and the Moon? And what about manufacturers on Mars who depend heavily on Earth/Moon-sourced shipments of parts? Won't they want to use Earth-standard fiscal years?

The answer to that is clearly NO! Until new methods of interplanetary propulsion antiquate the term "launch window", the one overwhelming Fact of Earth/Moon - Mars trade will be their mutual orbital synodic period which determines the frequency of launch windows. And this period coincides with neither terrestrial nor martian years, but averages 780 standard days or 760 Mars dates, some 25.6 months.

In short, business considerations may well lead some Martian enterprises to adopt fiscal cycles other than the 334/5 date civil Calendar we proposed for Mars. But even if Earth UT Time & Date provides a common shipboard reference time throughout the System, *on* Mars, businesses and settlers alike will live, work, and dance to more locally appropriate drums. **<MMMM>**

Are there METEOR SHOWERS On Mars?

By Harald Schenk

As the Sun sets behind a rock-strewn horizon, a spacecraft named Viking prepares for yet another lonely night.

Quickly, the heavens transform into deep blue velvet, revealing a splendor unequaled on Earth. It is nighttime on Mars. One of the many since Viking settled upon the alien surface, yet this one will prove to be quite different.

Suddenly, a flash of light illuminates the landscape. Within minutes, this flash is followed by several others. Is Viking under attack by Martian forces? Are the imaginary inhabitants of H. G Wells approaching with their "heat rays" to finally rid the planet of this strange intruder?

While Viking is only a robot, human observers would soon recognize the truth. It is a phenomenon common even on Earth. These flashes of light are nothing more than the individual members of a meteor shower.

Does this really occur? Does Mars indeed have meteor showers, and if so, how might they differ from those seen on Earth? The answer depends on several factors such as atmosphere and distance from the Sun.

Many years have passed since meteor showers were first associated with the orbit of comets. Composed of dust and ice, a comet will loose part of its mass with each passage around the Sun. Although this material has separated from the parent body, it may continue following the same orbital path for some time to come.

In this manner, comet debris can pollute the entire orbit, and continue producing meteor showers long after the comet has ceased to exist. If a planet enters any portion of this orbital path, it sweeps up some of the particles, and they in turn produce the celestial display we call a "meteor shower."

There are actually two types of shower. The one described above is called an annual shower, because debris seems to fill most of the orbit. There are some comets that do not seem to contain much dust. Meteor showers from such comets are difficult to predict, because particles seem to cluster in groups rather than disperse along the entire orbit. This is known as a periodic shower.

There are a number of comets whose orbits intersect that of the planet Mars. Two of these are Comet Temple-Swift, and Comet Arend-Rigaux. To speculate as to what the showers from these comets might look like, we have to look at some orbital comparisons

On Earth, these flashes of light are due to the high temperatures produced when the particles enter our atmosphere. The temperature, in turn, depends on the velocity with which each dust bit strikes.

There is a range of maximum and minimum velocity with which we might expect meteors to pass through an atmosphere. Minimum depends on the velocity required to orbit a particular planet. For Earth, this minimum velocity is 48 miles per second. On Mars, the minimum is only 2.2 miles per second. [Any infalling material must accelerate in the gravity well to at least these velocities.]

The maximum possible velocity would be obtained by an object entering the Solar System from interstellar space, and moving in a retrograde orbit (opposite to that of the planets). This can be calculated by adding rotational and orbital velocities, plus the escape velocity from the Sun at the point of impact.

For Earth, this turns out to be a maximum velocity of 45.0 miles per second. On Mars, the maximum is only 36.4 miles per second.

These maximum values are not reached because meteoroids (as scientists call meteors before they enter the atmosphere) travel in closed orbits, and therefore have much smaller velocities.

The average meteor shower is caused by particles the size of a grain of sand. Due to the high impact velocity, these tiny specks are vaporized at altitudes 70 to 50 miles above Earth's surface.

On Mars, with a much thinner atmosphere, vaporization would not begin until the particles had reached much closer to the surface. This would have the effect of stretching the radiant (direction our of which the particles appear to come) over a much larger portion of the sky. The smaller velocities would also increase chances that some of the particles might reach the surface.

Does Mars have meteor showers? The answer may have to await the arrival of men from Earth. Viking's eyes have been turned off for some time, and were not suited for recording such brief flashes of light.

[Note: This piece was written in 1989. Since then, Pathfinder and the two Mars Exploration Rovers, Spirit and Opportunity, have been on Mars, but the same remarks about these rovers visual abilities also applies.]

MMM #41 DECEMBER 1990

IMAGINEERING MARS ROVERS

By Peter Kokh

When you consider the immensity of the challenge (Mars' surface area is equal to all Earth's continental land masses combined) present architectural strategies for constructing Mars Rovers, automated or not, NASA or industry, seem patently inadequate.

To spend some exorbitant amount of money creating a vehicle that can range only a few score miles from the landing site seems to imply pre-acceptance of an Apollo-like "science-picnic" scenario- we go, look around, and come back home, never to return. For, *if we are serious* about opening up Mars for eventual human settlement, we *ought also to be serious* about designing globe-ranging vehicles from the outset.

What does that imply? Until we have graded highways cleared of boulders, wheeled vehicles are quite inappropriate. Most of the Martian surface, so far as we have explored it from our Viking Orbiters and Landers, is a continuous "strewn-field" - a 'Maginot' obstacle to wheels and tracked vehicles. While walkers would seem to be indicated, the ideas so far being put forth to make them self-navigating are absurd. Again, to spend millions developing anything whose usefulness will not extend beyond the limited scope of a first landing expedition - a radius of a few miles - is a waste of time. Self-navigation software that allows a vehicle to either wheel or walk at only a couple of hundred feet an hour is not what we ought to be spending our time on. What we need is a Broken-Field Runner!

JPL is testing a system using stereo cameras to provide 3D maps of the terrain ahead which the rover's computer will analyze to decide on the safest course forward, repeating the process every 15-25 ft! Can you imagine Olympic Games races on such a basis! *WE NEED* a heuristic software program that will allow the Rover to learn from experience, gaining confidence and speed. No human runner, negotiating an obstacle course, ever proceeded on the basis JPL proposes.

A good software program would allow a Rover, walking of wheeled, to recognize generically familiar patterns, attention focused *only*, and time-savingly, on the SIGNIFICANT differences AS they pop up. This, certainly, is how we do it - often even below the threshold of consciousness. Now a proper program designed in such a manner may make for slow learning at first. But there is no reason why a heuristic Mars rover can't do most of its learning right here on Earth in 'Marssimilar' terrain! Once on Mars, it would have to go slow for the first few moments while it adjusted its reaction patterns to the different gravity level. If all this is beyond our current level of expertise in Artificial Intelligence expertise, then perhaps we ought to set this project aside - until we are ready to do it justice. Why spend millions only to create some quaint anachronism, which is more likely to grace some dusty museum hall than the dusty plains of Mars?

If *suitability for Global Mars Access* is to be our faithful guide, surface contact rovers, whether wheeled or legged, should not be the only option we explore. Even though Mars' air is rather thin, we should be able to engineer ground-effects skimmers - especially if they are equipped with hydrogen-filled buoyancy bags to neutralize most of the weight. (Hydrogen cannot burn in the carbon dioxide atmosphere of Mars). "Skimmers" would provide a swift means of personnel and cargo transportation by route of choice over a large percentage of the Martian landscape. Personally, I cannot see the sense of sending an expedition to Mars not so equipped. Skimmers could range in type from 'jeeps', to buses, pick up trucks, even analogs of our "18-wheelers".

Skimmers would free the opening of Mars from the Roman precedent of prior construction of a network of trunk roads. Bottled Methane and Oxygen, processed from the air, could run their engines, re-releasing Martian air as exhaust, and perhaps saving the steam.

Space enthusiasts should continue to be very suspicious of unnecessarily self-limiting schemes for Mars exploration. As the old saying goes, *anything worth doing, is worth doing right.*

RETHINK MARS SAMPLE RETURN*!*

Commentary by Peter Kokh

We definitely do need to know more about the chemical and mineralogical composition of the Martian surface along with the geological heterogeneity with which such potential resources are distributed. And we should have this knowledge in hand BEFORE we launch a crewed expedition! But is the Mars Sample Return Mission the way to gain such knowledge? We think not.

First, unlike the Moon, Mars is much more diverse from place to place. One or even a few sites sampled for return to Earth would give us a very skimpy knowledge at best. Rather we should launch a Mars ORBITAL Retrieved Sample Examination LAB (or MORSEL) to which a whole FLEET of surface samplers could send their troves. *Better to sample more areas, examining them in Mars Orbit, than fewer areas, sending the samples all the way back to Earth.* A greatly reduced sample bag of tagged soil and rocks defying analysis or yielding enigmatic results could then be sent to Earth after the great bulk of the samples had been satisfactorily characterized aboard this automated orbital pre-examination facility. This would also supply a "ground truth" calibration check.

If we can't yet build such an automated lab, let's start brainstorming now. how to go about doing so. MORSEL would give us a more adequate picture of Mars.

LUNAR DEVELOPMENT & MARS

Commentary by Peter Kokh

If some would ignore the Moon, it is in our deepest self-interest not to return the snub. No one should put all their eggs in the same basket - here we are referring to building the LUNAR ECONOMY on the sole foundation of supplying energy to Earth, through either or all current scenarios: Solar Power Satellites in GEO, Lunar Surface based Solar arrays, or a Helium-3 harvesting operation for future fusion plants.

If one's sole goal is to build space colonies as a *by-product* of Solar Power Satellite construction, what ultimately happens to the Lunar Economy may seem unimportant. But *we* think that reaching a stage of healthy self-sufficiency for the Lunar Economy is probably the best choice of granite out of which to carve the cornerstone for a truly CIRCUMSOLAR civilization. If *this* viewpoint is on the mark, then it becomes rather *important to DIVERSIFY* the Lunar Economy. Serving the needs of pioneers opening Mars, is surely one such promising avenue for expansion.

Mars itself has nothing to sell the Earth except tourist meccas for the obscenely wealthy. Its moonlets, Phobos and Deimos, most likely are well endowed in the volatiles the Moon lacks. And any developing Lunar Settlement will be steadily acquiring the capacity to self-manufacture the more weighty of its needs to keep its trade balance with Earth as favorable as possible. It will be just such items that the Mars Settlement will need also and which the Lunans can supply at a definite fuel=cost advantage over similar items from the Earth's gravid surface. It is a two-way trade natural.

Until the Martian Settlement develops a diverse enough industrial base to shun trade altogether and turn in on itself - something the Moon happily will never be able to do - the more Mars' economy grows, the more the Moon's economy stands to grow in linkage.

The same is true vis-à-vis the Asteroids. The Moon, with a gravity well shallower than either Earth's or Mars', and with shorter synodic 'windows' to the asteroid belt than Mars, is much better situated than either Earth, LEO, or Mars to serve as the major outfitting and supply base for efforts to exploit the promised wealth of the asteroids, Earth-approaching OR Main Belt. The more the rest of the Solar System is opened up, the more the Lunar Economy should grow.

Mars *should fascinate* would-be Lunans! - PK

"One doesn't discover new lands
Without consenting to lose sight
Of the shore for a very long time."

\- A. Gide

TEMPTATIONS TO ECO-CARELESSNESS

Commentary by Peter Kokh

Paradoxically, there will be little room for Lunatics and Lunacy on the Moon. Our biospheres on that desolate globe must be fully closed for economic reasons grounded in the need to import three of the four elements most essential to life: hydrogen, carbon, and nitrogen [oxygen being abundant on the Moon]. Not to religiously recycle "exotics" would be prohibitive.

When we get to Mars, the settler pioneers can expect a reprieve of sorts. The thin Martian atmosphere, with just 1/140th of Earth's atmospheric pressure, can yet be "mined" by well-known means to produce water, an Earth-normal air mix for habitat pressurization, and even oxygen/carbon monoxide and oxygen/methane fuel combinations to run vehicles, generators, and other equipment.

This undeniable head start advantage towards self-sufficiency has fooled many. The inventory of indigenous raw materials is not the whole key to economic self-sufficiency. If it were, Japan would be one of the World's poorest countries. The point is that Mars has nothing but tourist spots to market to Earth in exchange for those things its infant industries can't yet produce for itself; whereas the volatile-impoverished Moon has the far more important triple pluses of *"location, location, and location."*

Nonetheless, the *Rusty Dusties* pioneering the mountain slopes, canyonlands and plains of Mars will find themselves tempted to exhaust their pollutants to the outside atmosphere and soil, since fresh replacement atmosphere and water is, relative to the harsh lunar experience, so cheap and easy to re-process from the generous surroundings.

Atmospheric winds will sing a siren song: "We offer an inexhaustible sink for your cares." Dirty water will freeze, not mixing with the pristine permafrost from which fresh water is drawn (one of the water options.) We are so few, our settlement so small, and yet Mars is so big! What can it hurt?`

Even James Lovelock, of Gaia Hypothesis [1] fame, suggested in another book, The Greening of Mars, [2] that we use abandoned military missiles, ganged together to provide the necessary staging and delta-V, to rocket to Mars all of the stockpiled chlorofluoro-carbons (CFC's) that we dare not use up on Earth if we don't want to destroy the last vestiges of the Ozone layer. On Mars, where we can't breathe the air anyway, and where there is no ozone to destroy, a CFC greenhouse effect would be most welcome. Fine! – *if* we are *never* going to *"terraform"* Mars! But if we are to leave open such a possibility for later more populous and capable generations of Martians-to-come, had we not best be careful about rushing down some potential *cul-de-sac*?

Dire prediction: *IF* Mars is settled *directly* by Earth folk laden with bad habits, instead of by seasoned Lunans living right, eco-disaster will occur.

References:

[1] Gaia: A New Look at Life on Earth by James Lovelock 1979, 1987. [2000 edition: Oxford University Press, ISBN: 0192862189

[2] Greening of Mars by Michael Allaby, James Lovelock [1985 Reprint edition Warner Books; ISBN: 0446329673] – PK >>>

To Inject a Unique Flavor into Martian Settlement Culture, add the Romantic Touch of Old

Barsoom

By Peter Kokh

When European settlers first arrived in the Americas, they brought many place names with them: (New) York, Boston, Norfolk, Birmingham, Cartagena etc. They reached into the pages of antiquity for other names: Memphis, Cincinnati, Atlanta, Phoenix. But often enough, they were quite content to adopt native names for places, or Anglicized versions thereof: Seattle, Tacoma, Chicago, Milwaukee, Chattanooga, Wichita, Quito, Mexico, Bogota etc. Using Indian names not only helped cut ties to the various motherlands, but gave the New World a special flavor.

When and if settlers come to Mars, they will have an assist from the list of features already named by the International Astronomical Union following their identify-cation on orbiter photo-graphs. In naming settle-ments, they can refer to such pre-named natural features as a starting point e.g. Marineris Heights, Port Pavonis etc. They can also use baggage-names from Earth: New This and New That. But to supply "Mars the World" with that special colorful indigenous touch?

While native Martian names are not available, strictly speaking, Mars *has been previously populated* in various romantic Science-Fiction novels and in the pseudo-scientific overreachings of Percival Lowell and his many followers. If we build aqueducts to bring melted polar cap ice to the equatorial zone, why not assign them romantic names from Lowell's list of imagined canals?

Perhaps the most elaborate fanciful glimpse of Mars was that of Edgar Rice Burroughs, the creator of Tarzan, who wrote ten or more novels about *BARSOOM* over a thirty year period from 1911-41. What harm could there be in immortalizing some of his Barsoomian city names and names of his heroes, heroines, and villains?

In a planet of unrelieved ocher, rust, red, orange, pink, salmon, and coral shadings, a little literary color would be most welcome – a helpful assistance to the pioneers in seeking to establish a new collective identity, a symbolic declaration and reminder that "This is *not* Earth!"

Here are some of the Barsoomian city names which might be lifted out of fiction and into reality: the most famous, the twin cities of Greater and Lesser Helium (with their mile-high towers, pneumatic tubes, the great Avenue of Ancestors); then the storied *seaports* of old Aanthor (Avenue of the Quays, mono-liths), Hastor, Lothat, Thark, and Xanator; other cities such as Amhor, Duhor, Exum (on the equator at the Prime Meridian), Ghasta, Gooli, Horz, Illal, Invak, Jahma, Kadabra, Kamtol, Kobol, Korad, Manataj, Manator, Manatos, Morbus, Morgor, Onvak, Pankor, Phundahl, Ptarth, Toonl, Tjanath, Torquas, Zodanga, and Zor.

Awaiting assignment to various real geographic features are the Anatolian Hills, Dor and Otz Valleys, Ompt and Shador Islands, Korus Sea, Torquas Mountains, Toonlian Marshes, and Omean subterra-nean aquifer-ocean. Names ready-made for regions or districts are

Domnia, Dusar, Gathol, Jahar, Jahma, Kaol, Okar, Marentina, Masena, Panar, Raxar, and Warhoon. A circum-Mars equatorial highway or mag-lev route, could take the 'old Barsoomian name' for equator: Polodona.

For Phobos the name pool includes: Thuria, Ladan, Ombra, and Tarid. For Deimos: Cluros.

Young settler girls could be given, or take, such names as Dejah (the famed Dejah Thoris), Haja, Janai, Lano, O Ala, Olvia, Ozara, Phao, Rojas, Sanoma, Sharu, Sola, Tavia, Thuvia, Ulah, Vaja, Vantija and Vanuma. Young pioneer boys: Carter, Carthoris, Djor, Floran, Gahan, Hovan, Jat Or, Kantos, Kulan, Lum Tar, Notan, Orm-O, Parthak, Ras, Sovan, Talu, Tars, Torith, Turan, Turjun, and Vandor – *villains excluded.*

If special plants are bio-engineered to thrive in Mars' climate some "local" names out of Barsoom's "past" are gloresta and pimalia flowers, mantalia and umpalla shrubs, sompus and usa fruit trees; and the trees skeel and sorapus.

If for pets, settlers breed novel varieties of cats, they might call them banths, komals, and soraks. New dog breeds could include calots and woolas; a new bird, the malagor. Large designer animals can be named orluk, thoat, and zitadar.

When the Mars Republic issues its own currency, it could be called the tanpi. And *ready now* to be instilled with life is the much-described *Barsoomian chess game*, Jetan, played on a board of 10x10 orange and black squares with dwars, padwars, panthans, princesses, thoats, warriors. Less defined is a game of chance called Yano in which small numbered spheres are rolled across a board with numbered holes.

Future Martians will develop their own fresh frontier customs. Taking cues from Burroughs' Barsoom, they might include: special remembrances of their ancestors, the exchange of armlets upon establishing friendship, laying of hand(s) upon another's shoulder(s) in greeting instead of shaking hands. "Kaor" could replace "hello" and "Good Day". At parting, goodbyes might be signified by hand(s) above head, palm(s) backward. And at weddings, the spouses-to-be might exchange gold ceremonial collars.

A regional governor might be called a Jed. If there is a chief planetary executive, his/her title might be Jeddak/Jeddara.

We'll certainly use the thin air of Mars for transportation, but the Martian planes or flyers will look like strange caricatures of those plying Earth's skies, their design driven by different ambient conditions. A small flyer design can be called a pinaar; a large airliner a vanator.

In seeking to establish a separate identity, the immigrants to Mars can either start from scratch or borrow from the imaginations of past writers. *A touch of old Barsoom would help!*

[* For more colorful tidbits, see John Flint Roy's 1976 A Guide to Barsoom: The Mars of Edgar Rice Burroughs – Ballantine, ISBN 0-345-24722-1-175] <MMM>

"No grimmer fate can be imagined than
That of humans, possessed of godlike powers,
Confined to one single fragile world."

-- Kraft Ehricke

IGLOOS

ATMOSPHERE-DERIVED SHIELDING FOR LO-REM MARTIAN SHELTERS

By Peter Kokh

Mars, despite its precious endowment of thin atmosphere, has a surface almost as naked to the cosmic elements as does the Moon. True, this blanket of dry ice vapor [Mars atmosphere is largely carbon dioxide] does intercept and vaporize most of the micro-meteorite rain from space. But it does little to temper the Sun's ultra-violet fury, a harsh fact of [non] life that constrains plans for someday "greening" those arizonesque Marsscapes. In truth, even full-strength UV does not penetrate very far; glass, as most other likely building materials, can serve as an adequate barrier.

Of far more consequence, Mars' air is no longer dense enough to appreciably absorb or neutralize the all points bombardment of cosmic rays, nor the ionizing radiation from the occasional solar flare. As on the Moon, it will be prudent for explorers and eventual settlers to provide massive shielding for any and all human spaces, fixed or mobile, in which they will be spending significant portions of their daily routines.

On the much smaller Moon (half the diameter, one tenth the mass, and only 42% as gravid as Mars), the handy regolith, the blanket of impact-pulverized soil which covers the surface everywhere some 2 to 10 yards (meters) deep, can be heaped up over our pressurized habitats and passageways, and on top of vacuum-exposed workspace ramadas or canopies. The conventional wisdom has been that we will do something similar with the rock-strewn sands of Mars.

But this Moon-appropriate technique, while it does provide a fall-back option, is hardly the elegant choice for Mars! *CONSIDER*:

1) The windswept Martian surface may not have so universally uniform a regolith blanket. Indeed, Viking I and II surface pictures show rock and boulder peppered plains in which the sand grains may be no more than a filler. Gathering up fine material for shielding mass would be a much more difficult trick, leaving a probable rockpile surface in the source area.

2) Because of this, a larger area of the neighboring surface would have to be disturbed unless sand were to be "mined" from remote or out-of-sight locations, an inconvenience at least.

3) For both these reasons, automated deployment of surface-derived shielding in advance of the arrival of human occupants – should it be desirable to land and check out base-habitat structures in advance – would be much more difficult to pull off on Mars than on the Moon. It would even be a tedious effort for teleoper-ators based on nearby Deimos [Deimos stays overhead of any Mars surface location far longer than does fleeting Phobos].

So why not look for options? Fortunately, the atmosphere of Mars provides abundant raw materials for a number of alternatives Here is its composition:

COMPONENT	Formula	%age	Snows at °C
Carbon Dioxide	CO_2	95.32	-78.5
Nitrogen	N_2	2.7	-210
Argon	Ar	1.6	doesn't
Carbon Monoxide	CO	0.07	-199
Oxygen	O_2	0.03	-219
Water Vapor	H_2O	0.03	0

(& Neon, Krypton, Xenon, Ozone, parts per million concentrations).

Now conceivably, we could provide *a bladder of appropriate shape*, probably of serviceable Kevlar, to either drape over habitat structures directly or over an overarching framework under which habitat structures could be tucked safely *and fill the bladder with liquefied or frozen gases condensed out of the Martian air.*

Voila! an IGLOO! Its a nice thought, but one look at those freezing temperatures would seem to put a damper on the idea. Such igloo-type shielding would seem to require insulation and/or refrigeration if its regassification point lay well below mean ambient temperatures. Of the above selection, only *water* would remain frozen or liquid through the whole range of Martian seasons. Indeed, water would be ideal for, liquid or solid, it would buffer serve as an excellent thermal buffer between interior and exterior. No insulation would be needed on either the elements-facing or the habitat-facing walls of the containing bladder. This water-filled comforter could drape directly over habitat structures, avoiding the extra bring-along weight of a separate supporting framework.

Except in the case of possible research or ice-mining stations along the edges of the polar caps (and then it would make even more sense to use water-ice!), a *dry-ice or dry-snow* (CO_2) filled bladder would have to be foil-faced on both sides and need to be separated from the shielded habitat area by some sort of trusswork, less it act as a heat-sucking sponge.

Alas, Carbon Dioxide is more than 3,000 times as abundant as water vapor in the Marsair. In comparison, it would take a lot more up-front energy to extract the needed water, a debatable tradeoff with the rather significantly more forgiving maintenance required.

To be sure, if tappable permafrost reserves are handy to the chosen base site, the decision would swing towards water. Installation of the required equipment will most certainly require the presence of an on site crew, however. So the water-ice option, as attractive as it may be from an ivory tower perspective, presents great difficulties for the starter base, even more so if the base is erected in automated or teleoperated fashion prior to actual occupancy.

Yet if it is decided that it is too expensive to import the water supply needed for the explorers' (or settlers') consumption, hygiene, food production, and processing needs, and tapping permafrost reserves is deemed to be impractical in the near term, then by one manner or another, atmospheric water vapor will be the one remaining choice. In that case, the equipment needed to extract it must be included in the base setup cargo, as well as a power plant sufficient for the chore.

So much for a first blush assessment of igloo shielding possibilities! Now it's time to take a deeper look and do a little brainstorming. *It is not necessary to limit our choices to the gases actually present in Mars' atmosphere.* Other freezable volatiles can be produced out of these, such as Methane CH_4, Ammonia NH_3, and so on. And as we have read in the first article, methane production along with Oxygen and probably Carbon Monoxide, are high priorities for even the Mars Beach-head Base. Ammonia production, for use as a chemical feedstock for fertilizer etc., is a lower priority but will follow soon enough if any sort of permanent human presence is to be maintained on Sol IV. *Ammonia* liquefies at -33°C and freezes at -78°C, and would be easier to maintain in a non-gaseous state than Carbon Dioxide. Can we do better? That is, can we find a compound producible from Martian air **a)** with a much higher gasification temperature and **b)** in much greater potential abundance than water vapor?

What about the *oxides of Nitrogen*? Nitrogen itself represents only a 2.7% fraction of Marsair constituents, but add in some of the Oxygen which comprises a whopping 60.7% considered element by element, and the potential abundance of various oxides of Nitrogen might be much greater than that 2.7%.

OXIDE	FORMULA	%age	Gas above °C
Nitrous Oxide	N_2O	4.24	-88.8
Nitric Oxide	NO	5.78	-151.8
Nitrogen Dioxide	NO_2	8.87	+21.2
Dinitrogen Pentoxide	N_2O_5	10.41	+47

Paydirt!? It certainly looks as if either Nitrogen Dioxide (and the polymer N_2O_4 co-stable with it in the liquid state) or Dinitrogen Pentoxide, which is a colorless crystalline solid (might need only a wind-breaker and not a full bladder!) could satisfy both of our conditions above. Isolated within the containing bladder, either would be sufficiently inert.

Consider too, that in the process of producing such oxides, appreciable *water for other uses, could also be produced as a by-product* (2.9 kg of water per ton of N_2O_5 and 3.4 kg of water per ton of N_2/N_2O_4). As hundreds, even thousands of tons of these oxides might be needed, this water could be a valuable asset.

What are the potential drawbacks of a scheme to produce either Nitrogen Dioxide or Dinitrogen Pentoxide from Mars Air for use as habitat shielding within a containing bladder? Obviously, it will come down to the relative ease or difficulty of the production process. Here on Earth, Nitrogen Dioxide is most economically prepared by reacting oxygen with Nitric Acid (HNO_3 which by the way has a potential abundance of 0.2%, seven times that of water vapor, and liquid below 83oC) or by heating a heavy metal (lead) nitrate.

$2 NO + O_2$ <u>*to*</u> $2 NO_2$

$2 Pb(NO_3)_2$ + heat <u>*to*</u> $2 PbO + O_2 + 4 NO_2$

Under Earthlike conditions Dinitrogen Pentoxide is most economically prepared by dehydrating Nitric Acid with Phosphorous Pentoxide.

$P_2O_5 + 2 HNO_3$ <u>*to*</u> $2 HPO_3 + N_2O_5$

The salient task at hand is *to identify and test out the most Mars-appropriate of producing either of these potential igloo-makers.* If a practical process can be worked out, such igloo-shielding could prove quite attractive and work to accelerate Martian development. To recap, the advantages over sand-scrounging would be

a) *leaving the surrounding terrain undisturbed* except for footprints and possible grading of roadways - a *scientific* plus and an *aesthetic* one too,

b) ability to be put in place automatically prior to crew arrival, and

c) its *compatibility with production of valuable water reserves as a by-product.*

To the writer's knowledge, this is the first sugges-tion of using igloo materials for shielding on Mars. If not, it is at least arrived at independently. <<< **MMM** >>>

Note: We wish to thank NASA scientist Geoffrey A. Landis for his response to this suggestion in which he points out that dinitrogen pentoxide is so unstable that it is classi-fied as an explosive. Are there ways to stabilize it, possibly with some additive also produced from the Martian atmosphere? If not, we could simply use pure carbon or graphite powder, which in the absence of free oxygen, would not ignite or burn.

The advantages of atmosphere-derived shielding are considerable, and it would be a pity to drop this idea without exhausting all the options and alternatives. PK

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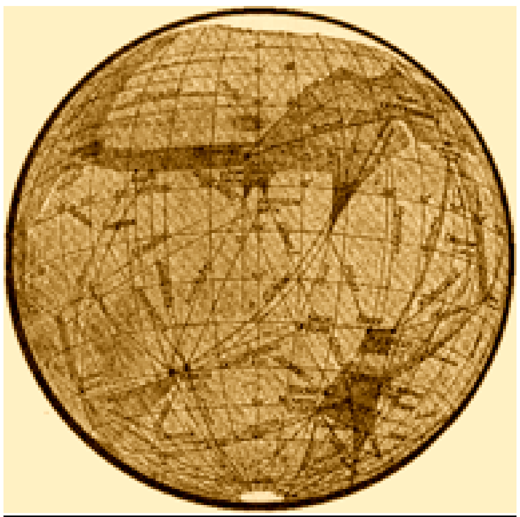
Mars of "Lore" vs. Mars of "Yore"



Above: Mars as Percival Lowell saw it, criss-crossed by canals, a dying, drying world that once had a thriving bio-sphere and given birth to a sentient race. "Martians" had since adapted to the thinning air and dwindling water reserves, building a network of irrigation canals.
Below: Mars 3 billion years ago, with its northern ocean. Today it is a far more hostile place than either. Should efforts to make Mars more hospitable seek ambitiously to restore the Mars of Yore - or settle for the Mars of Lore? ⇒ below.

[IN FOCUS Editorial]

MARS: plenty of time to wait, but none to waste

Plenty of Time to Wait

Most of us in the National Space Society see the make-or-break importance of putting our expansion into space on a firm economic footing and we view development of lunar resources as the first step to achieving that goal. Yet most of us also have a keen interest in Mars, its exploration by human crews, and its eventual settlement. While President Bush has espoused such a goal, economic realities are certain to put off its achievement for decades, like it or not. Even a magnitude of order reduction in NASA's original cost estimate of $500B via Bob Zubrin's "Mars Direct" mission architecture still leaves human exploration of Mars a luxury. Once the potential for off planet resources from the Moon and elsewhere to substantially alleviate Earth's growing energy crisis is more widely realized, this will change, with retrieval of volatiles from Mars' moon-lets, Phobos and Deimos, part of the scenario. Martian settle-ment will piggyback on that resource trade *or not occur at all*.

Meanwhile things do not look well even for robotic precursor missions to Mars. Mars Observer, much of its original potential lost when NASA cut the NIMS instrument as a penny-wise pound-foolish budget move, is set to lift off soon on a Titan using the unproven and inadequately tested TOS kick motor. We can only hope that Mars Observer will not be yet another victim of tragicomic human error, adding to the sorry string that now lists *Phobos*, *Hubble*, and *Galileo*.

Meanwhile the former Soviet, now the Russian Mars program has been cut back and delayed. Until the Euro-Asian Commonwealth economies improve dramatically, we can be thankful for any missions that are actually launched.

No Time to Waste

Those who wait for transportation cost breakthroughs and do nothing else in the meantime to help ensure the success of eventual Mars missions, work instead (in self-betrayal of

Meteorburst Communications - Design light-weight equip-ment to be included on a Mars Surface Rover to attempt to relay signals to distant receivers over the horizon by bouncing them off meteorbursts in the high Martian atmos-phere much as truck fleets now do on Earth. If successful, this would allow planetwide operations without the necessity of deploying and maintaining an expensive array of communica-tions satellites. A good project for ham radio buffs.

Carmonox and Methanox Engines - Develop, debug, and improve internal combustion engines (for vehicles and generators) that can run on Carbon Monoxide and Oxygen or on Methane and Oxygen in simulated Martian conditions. These fuels can easily be extracted from the local atmosphere and cached at handy points to bring real mobility to Martian operations. A pair of good project for the automobile engine buffs amongst us, or for school projects.

Skimmers - Earthstyle hovercraft will not work in the thinner Martian atmosphere unless a large portion of their standing weight (with fuel, and without) is neutralized by gaseous hydrogen buoyancy tanks. Maintaining stability in maneuvering, and maintaining ground clearance range as fuels are used up will be a design challenge. If you have the capacity to tinker up a suitable Mars skimmer and don't, don't cry when our people on Mars are dependent on torturously slow walkers or crawlers when they could have been making tracks.

Canals for Polar Meltwater - One should never put all one's eggs in one basket. As permafrost may prove not to be an easily recoverable resource, we need to brainstorm how to access the much greater water reserves within the planet's polar caps. Do we truck quarried ice to distant bases and settlements? Or do we finally build the vaunted canals of Mars, once prematurely accepted as fact? If so would these be pressurized conduits carrying melted ice water with periodic pumping stations and measures to keep the water from freezing (such as solar heat-attracting and storing surfaces)?

CHEMICAL ENGINEERING PROJECTS

Igloo Type Shielding - Dinitrogen Pentoxide (N205) produced robotically from the surrounding atmosphere without disturbing the surrounding soil of the base or settle-ment site, would make deployment of either, a much simpler task and produce other useful volatile feedstocks as byproducts. We need to brainstorm the most appropriate chemical path-way for producing this stable radiation-shielding powder under Martian conditions and with a minimum of tending.

Once we have a much, much better handle on what types of mineral and chemical compositions occur in how much relative abundance in the various areas of Mars, it will be time to start brainstorming the processing of building materials and other products from local resources. As of now, such work would be premature - garbage in, garbage out.

Climatic Engineering by design - By now we know, having learned the hard way, that human industrial activity has a definite changing effect upon the terrestrial biosphere. While the effect of our presence and industrial activities on Mars will be minuscule at first, they will be real. On Mars the situation will be just the opposite. We will want to maximize, not minimize, climatic change-effecting byproducts of our activities. But first we must decide what our "terraforming" goals are. Some of the potential pathways may be mutually exclusive. It will be important not to put in place operations that will unwantedly commit us to temporary but "dead-end" greenhouse improvements. See the article that follows. The result of this discussion should be to have in hand, when we finally do set up on Mars, a well thought-out **strategic exhaust gas policy**.

AGRICULTURAL PROJECTS

Mars-Hardened Plants - At the present epoch, Marsair is too cold, too thin, too dry, and too naked to raw UV to support any kind of plant life useful to settlers that we can easily imagine. Yet condensed and warmed in moisture tight greenhouses under UV resistant glass, Mars' Carbon Dioxide - Nitrogen atmosphere (95%, 3% respectively),a small amount of Oxygen added, should support agriculture easily enough. It's not too early to begin breeding and bioengineering (transplanting genes that promise success) plants that "thrive" in such conditions, gradually hardening them to ever thinner, cooler, drier, and less oxygen-rich conditions until one day, as human planetary engineering improves the climate on Mars, they can establish themselves outdoors and spread, creating the first (in a very, very long time, to be sure) Martian ecosystems. Meanwhile crops grown in such conditions will provide food, fiber, and feedstocks much more cheaply than those that have to be babied in more Earthlike greenhouse conditions.

An important consideration in the above scenario is the choice of plants that are not dependent for pollination on insects of other animals that could not survive in such anaerobic (oxygen-starved) conditions. Mars will have flora outside the greenhouse *long* before it'll have fauna outside the zoo.

PROBE INSTRUMENTATION PROJECTS

If we are going to settle Mars, living off the land in true frontier style, we must have in hand a much better picture of the nature and geographical extent of potential Martian resources. Our past probes, and those now in the works, both U.S. and C.I.S., are aimed less at resource identification and mapping, than at the intellectual self-gratification of the principal investigators enlisted in the effort. This knowledge is not spurious. It does provide a foundation for further exploration. The point is that if we do not see to it that future probes are adequate to the job we who would settle Mars need them to do, we cannot sit idly by and leave the choice of instruments and the scope of missions to planetary scientists planning alone.

A **Permafrost Explorer** needs to be brainstormed. By first scouring over existing Landsat thematic imagery to find clues to Siberian, Alaskan, and Canadian permafrost - here on Earth where ground truth checks and calibrations are an easy matter, a project team should be able to get a handle on how to design a Mars probe that would do the trick, outlining the extent and perhaps giving clues to the thickness of subsurface ice-laden soils on Mars. A spin-off *precursor* dedicated Earth Permafrost Explorer would be a funds-attracting possibility.

Carbonate Explorer - Orbiting thematic mappers might be optimized to expose calcium carbonates (limestones) in the soil and other depositories of carbon dioxide that could be used to *re*thicken the atmosphere. It is even possible that there exist karst regions of long dead limestone caves preserved through the disappearance of running water.

Thermal Explorer - An orbiter could be instrumented to map the relative heating and cooling (post sunrise and post sunset) capacity of various areas and to reveal geologically active hotspots that could be tapped someday for geothermal power production.

Future topographic mappers could be made sensitive enough to reveal ancient shorelines and beaches, tiny headwater sources and eroded badlands. Chemical mappers might be made sensitive enough to reveal salt deposits, clays and other rusted and hydrate-rich soils as well as hydrogen depleted soils.

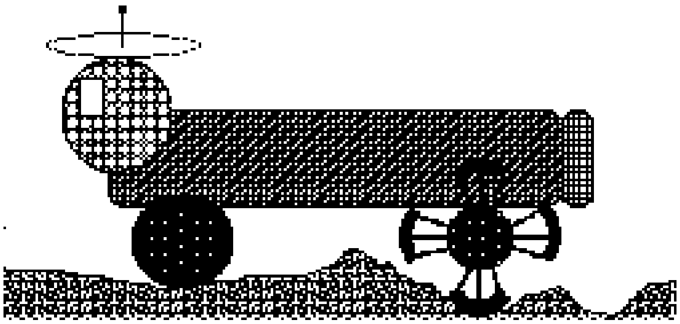
The implications for all this knowledge for base- and settlement-siting, for architecture, for industry, and for agriculture cannot be underestimated. Without such knowledge, we will founder about blindly, losing decades. NSS has several members with at least some of the germane expertise to take a more aggressive tack in planning the future of Mars precursor missions so that when we do go to Mars, we will have gone to stay, really.

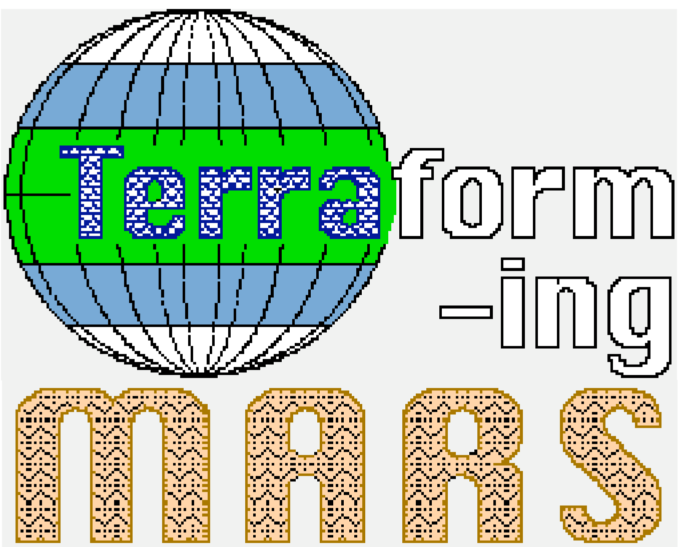
These are just a few items of an ambitious homework agenda to make the waiting years anything but wasted ones. As we identify more in MMM, we will add them to this list. But the choice is up to us as individuals and subgroups, since the NSS Board seems disinterested in doing anything other than affecting public policy. **PK**

INVENTORS WANTED

Serious would-be explorers of Mars have been busy developing a variety of wheeled and walking vehicles and robots to cover the boulder-strewn expanses of Mars.

The trouble with wheels, is that they are too easily defeated by a host of obstacles. Mars has no roads. Yet walkers can negotiate easy terrain at only a snails pace. So why not combine the virtues of both? Tinker a walking vehicle that can let down a set of wheels when the way gets easy, or a wheeler that can switch to legs, or whose tires can sprout feet?





To date, the discussion can be summed up by the phrase "garbage in, garbage out"

By Peter Kokh

When the popular wisdom that Mars was a dying planet populated by an ancient race that has struggled resourcefully to keep apace with the advancing desiccation of its lands and the thinning of its air with a grand engineering scheme of canals to bring melt water from the polar caps to thirsty equatorial croplands and of atmosphere plants to keep the air as thick as possible - when this notion finally fell before the onslaught of better telescopes, less romantic observers, and an armada of visiting probes, many a writer made up for his aching disappointment by concocting schemes to make this drier than we thought, colder than we thought world something more like Earth. "Terraforming" is the word in currency. And the number of daring bold schemes is legion.

There are two things wrong with these schemes. *First* there has been little if any consideration for where the planet has been (should the goal be rather one of restoring the pristine youthful Mars of yore i.e. **"rejuvenaissance"** rather than "terra"forming, bringing it to a state alien to its experience?)

Second there has been much detailed consideration of importing apparently missing volatiles (notably water-ice and oxygen) and little consideration for what resources are actually banked on the planet itself in one form or another. Indeed we do not know the answer to that and a whole armada of probes will be needed to tell us what level of improvement we can achieve *working with the grain of Mars*, rather than against it.

Indeed such information may well make clear that we could, without grandiose schemes to import ice from Hyperion or elsewhere, *ease Mars back*, if not to the ocean-mantled days of its youth, at least to the marginally survivable world we thought was our neighbor some decades ago. Yes, why not **"Lowellification"** after Percival Lowell whose inventive picture of Mars so many had so eagerly swallowed hook, line, and sinker - a vision of broad irrigated croplands beside wide open canals, of the spring advance of green from poles to equator, of air not so thin that a simple breathing mask wouldn't do, of deep blue skies to offset the rust-hued sands.

In fact, we may not need to import ice from elsewhere in the Solar System to give Mars new seas. We won't know that until we've orbited a **Permafrost Explorer** and a companion fleet of ground truth seeking robots. Yet no nation has gotten past the "wonder if" stage of curiosity about permafrost. Without advocacy we may never get to know. For it is the relics of the past, not the foundations of the future that causes planetary scientists to itch, and seek federal scratching aids.

In truth, we may not need to import vast quantities of oxygen and nitrogen to transform the atmosphere if orbital and surface exploration reveals vast buried fields of carbonate rocks or even limestones. We haven't heard of any plans to research these pregnant possibilities. For if we could thicken the given carbon dioxide atmosphere, we'd have a warmer Mars, one on which some frozen water reserves would melt and stay liquid, and one on which, a trace of oxygen added [%?], plants not dependent on animals or insects for pollination could thrive - even if we still could not breathe the stuff ourselves.

And if, no thanks, we would rather move towards an oxygen-laden nitrogen-buffered atmosphere like the one in which we have ourselves evolved, we may have an assist of unknown potential in the surface peroxides of unknown depth and extent that the Viking experiments hinted at. Can we get a handle on this question from orbit with the help of calibrating ground truth devices on the surface? Those who would go beyond exploratory orgasms to real settlement, owe it to themselves to advocate the missions that will tell us yea or nay.

We may or may not ever have enough raw power at our disposal to undertake the grandiose terraforming schemes bandied about in the past three decades. But we will certainly have an effect on Mars, as we have had on Earth, by our growing industrial presence there. Even before we have the wherewithal to begin tackling a more modest program of "Lowellification", we will have the option of designing our industrial processes to maximize the kind of benign exhaust "pollution" that would slowly build up to the threshold for permanent climatic change for the better.

Decisions will have to made in the next few decades, as soon as possible, about what our goals are for Mars - for the various paths are not all stages of one grand scheme. If we will settle for a much-easier-to-implement thicker CO_2 atmosphere with a relatively small amount of free Oxygen and accept a Mars-hardy vegetation without wildlife (we'll have indoor pets and "middoor" urban wildlife to be sure) then the industrial protocols we need to put in place from the gitgo will be quite different from those that would support a path to a more Earth-like final result.

Before we pick sites for our settlements, we had best make sure they are not smack in the way of some eventual river, or on the bottom of some future sea!

If we purposefully take the first humble steps to a future wetter Mars, then, before we pick sites for our settlements, we had best be sure they are not smack in the way of some eventual river, let alone on the future bottom of some sea to be. Indeed, we have a very poor map of Martian topography and the relative elevations of various areas. Mars was not wet enough long enough to have developed a mature drainage system - even if it did have a pole-girdling northern sea, Oceanus Borealis, and even if it did have catastrophic flooding in a few scattered episodes. Mostly Mars will be a place of separate unlinked basins whose lowest sills have never been breached. Not only do we have to have an excellent basin map, we have to know what the soil composition of various basin sills are, and the ease at which water can cut a channel through them. Only with a lot more information than any curiosity-scratching planetary scientist has ever proposed to seek could we program a computer to sketch the likely evolution of Mars future drainage systems.

Not only do we not want to place a major Martian settlement in the way of some future watercourse, neither would we want to isolate it in some future boondocks nowhere near one of the future rivers, lakes, or seas. There are a few safe bets, of course: on the rim of Valles Marineris, or on the upper flanks of the deep Hellas basin.

Any intelligent plan to settle Mars needs to know what resources are available and where they are to be found, in search of a healthily diversified economy. By these standards, we have not yet done enough homework that any plan for opening Mars could expect more than a pathetically flunking grade. The location of future Martian towns and cities, the "language" of any native architecture taken from the building materials that can be produced from indigenous resources in various soil provinces of the planet, even the kind of "forests" and "scrub" that we may someday be able to develop to grow wild and free under Martian skies, and the produce and fiber we may be able to harvest from such de-tamed varieties - all hangs in the balance. For it will depend heavily on the informed decisions we make on the direction of planetary changeover that economic micro-decisions will move us towards. The pace of that change may be slow but it will be inexorable.

Above all, we must be sure that we do not develop habits on Mars that start us up some dead-end canyon of foolish short-lived improvement. We must leap into the future from a platform of solid investigation.

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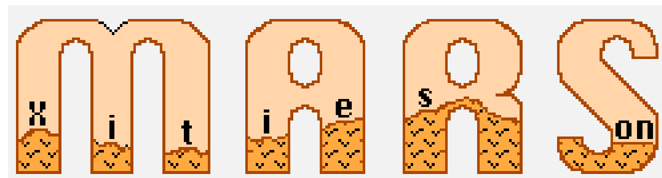
Terraforming, Rejuvenaissance, Lowellification?

The burden is ours, not to decide, but to begin the methodical accumulation of the information on which an informed and timely decision can be based.

Terraforming, Rejuvenaissance, Lowellification - whatever course we would choose - are not mere exercises of fantasy speculation. Nor do they represent choices we can leave to our successors in some latter century. The time is upon us, not now to decide, but now to begin methodically accu-mulating the information on which an informed decision can be based in a timely manner. Once a goal has been agreed upon, there will be time enough to decide upon the actual means. Meanwhile, sorry to disappoint those looking for an 'MMM special' quantum leap in speculative planetary engineering. As we said, at the present moment it's a case of garbage in, garbage out. And if those of us who ought to care, do not take needed steps, that situation will continue.

We can *chose to be the ancestors* of generations of Martians yet to be born. **<MMM>**



By Peter Kokh

The first settlement on Mars will probably be built on some committee-chosen site that has no justifying rationale at all to anyone looking at Mars from a long term global perspective. Such is the way governments do things. Xitizens and business people looking to found follow-up settlements will be much more strongly motivated to choose sites that offer distinct and inarguable economic advantages. For example, a position astride an obvious future traffic route, or near known or strongly suspected local resources of Mars-global significance, or near local energy access sites (polar meltwater-run hydroelectric? geothermal?) or, convenient to premium tourist attractions.

It often seems, even to lunar development advocates, that the Moon is very homogeneous and monotonous, that, to put it tritely, "when you've seen one crater, you've seen them all." Yet various lunar sites do offer distinct advantages and the Moon cannot be developed in any rational way by a single base or settlement no matter how respectably sized and thoughtfully situated.

If that is true on the Moon where eons of geological processes in the presence of water did *not* occur, the economic geography of Mars, where water flowed freely for perhaps a billion years, is likely to be far more diversified in its economic relevance. Strategic metals may well have begun to be concen-trated into ore bodies in various places. These may be exposed here and there in the walls of various canyons, favorite early sites for prospecting. The permafrost will be much more acces-sible in some areas than others. Very low areas like the Hellas basin will have noticeably higher atmospheric pressure, etc.

At this point we have a much better idea of the kinds of building materials that we can make from Lunar resources than may be possible from Martian ones. Given the almost certain high degree of variation in mineralogical content from place to place on Mars, even the most educated guesses as to the kinds of construction products we can produce on site are in all honesty little more than exercises of unanchored speculation. As a result, far more than on the Moon, various Martian towns may differ markedly in architectural appearance.

Beyond such a blatantly general statement, it is still possible to say some interesting things about future Martian Xities. First, since the degree and mix of exposure to the cosmic elements differs, shielding requirements will be both less and different from those on the Moon. The thin atmosphere is a poor blocker of cosmic rays and it has little screening effect on the strongly antiseptic solar ultra-violet radiation. But this tenu-ous envelope does stop most micro-meteorites and the danger of impact decompression accidents may be a bit lower. There is every reason to believe that the air pressure can be increased substantially by using Mars' own indigenous resources.

Shielding needs can be served in the same manner as on the Moon, using local regolith. This will be harder to accomplish if all sites are as boulder strewn as the two visited by the Viking probes. But there is also the elegant possibility of processing an insulating powder directly from the atmosphere - Dinitrogen Pentoxide or N2O5 [see MMM # 42 FEB '91 "IGLOO Shielding on Mars". See MMM Classics #5] To keep it from blowing away in the Martian winds, this powder would have to be covered with an anchored tarp or placed in bags, or simply in sufficiently voluminous hollow walls and roofing.

One site that has a lot going for it, the west slope of lofty Pavonis Mons on the equator, may also come equipped with ready made shelter in the form of innumerable lava tubes honeycombing the bulk of this great shield volcano. [cf. MMM # 18 SEP '88 "Pavonis Mons". MMM Classics #2]

[**See** request for proposals at the end of this article.**]**

While there are extensive dendritic valley complexes most likely carved by flowing water billions of years ago, a Martian analog of a Lunar rille bottom settlement [as in LRS' '89 Prinzton design competition entry] may be inadvisable if there is any chance at all that through human action the waters could flow again. Yet, as the atmosphere thickens slowly through planned industrial out-gassing and more swiftly through deliberate direct action, once the Martian economy can support such an effort, the settlers will be able to spend more and more time outdoors without overexposing themselves.

While shielding will still be a must, Martian xities need worry less about being air-tight, on two grounds. First, leaking oxygen into the surrounding atmosphere will help contribute to desired slow change in atmospheric composition. (On the Moon, similar leaks would degrade a scientifically and industrially invaluable high vacuum.) Second, whereas any leaks on the Moon would result in the loss of Nitrogen which may have to be imported to the Moon at great expense, similar leaks on Mars will lose nothing that can't be replaced locally.

While the practical differences are slight, Martian settlers may be less accepting of a "mole" type life (even with piped in sunlight and periscopic picture windows) than will be frontier folk who settle the harsher Moon and asteroids. Domed xities - even if the dome-facing walls of the buildings inside have to be shield-thick - may be the Martian settlers' common dream vision of the future, with some slow relaxation on the annual permissible number of unprotected hours outside.

Given the comparatively relaxed concern with closing the atmospheric and water cycle loops on Mars, smaller rural outposts will be much more practical than they will be on the Moon where there will be a much stronger biospheric advantage to size.

[MMM #15 MAY '88 "Rural Luna." MMM Classics #2]

Because wood and paper and plastics do not contain elements that are deficient on Mars, such materials can provide some of the building materials and furnishings and arts and crafts objects used in the settlement. In that respect, Martian burgs will be far more reminiscent of those on Earth than the glass, metal, and ceramic dominated lunar towns and habitats. Along with this benefit will come increased danger of fire.

Finally, unlike almost everywhere else in the Solar System beyond Earth [Europa and Titan may be two eventual exceptions very far down the road] Mars may someday (again?) sport a global biosphere of genetically nurtured adaptations of the hardiest Earth plants. Thus where all other Xities provide a firmament between contained biosphere and sterile and barren surroundings, on Mars xities will contain oases of Earth life surrounded outside by fledgling Mars-hardy adaptations. Towns on the red planet may actually someday get some of their food and other agricultural needs from outside their xity biospheres. **<MMM>**

Attention Technonuts, Software buffs

REQUEST FOR PROPOSALS:

Problem: How could Microbot Lavatube Mappers do their job within the maze of lavatubes that probably honeycomb Pavonis Mons and other Martian shield volcanoes if they're at all like their much smaller cousin on Earth, Hawaii's Mauna Kea/Mauna Loa (i.e. the Big Island, where incidentally they could be field-tested - as well as in the Oregon Moonbase) *without* losing their bearings underground, *and without* losing contact with their central control and information dump?

Answer: Let us know how *you* would design an army of robo-ants to thoroughly map and explore the suspected lavatube complexes on Mars. Assume that the mechanical critters will deactivate when they reach an obstacle or dead end and not return for debriefing. The "Reporting Center" may be on the surface or in synchronous orbit above the mountain.

MMM will publish the best suggestions submitted. COPYRIGHTs remain with the submitter, as usual. *

GLOBAL ACCESS to MARS the WORLD

By Peter Kokh

We will not have established a *real permanence* on Mars *until* we have made a start on an network of strategically scattered settlements, each differently advantaged by the geography and/or geology and mineral wealth of its site - as a down payment on a Diversified Economy that can supply a healthy percentage of its own needs and produce enough goods for export to purchase what the Mars Frontier jurisdiction cannot yet provide for itself. It is not enough to go beyond human exploration to the establishment of an outpost, however ambitiously designed. The permanence of that outpost will be so much wishful bravado against the harsh economic night until our presence on Mars becomes a real, rooted global occupation. As we've pointed out, we have a lot to learn about Mars, information that will not be gathered from the idle curiosity scratching probes now in the planning stages, before we can begin to glimpse what such a network of frontier towns would look like or the details of its economy.

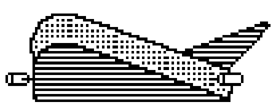
What we *can* do, while we are trying to escape owning up to our responsibility to get involved in advocating the needed set of Mars Resource Explorers, is to brainstorm, tinker, and field test various potentially promising means of transportation that settlers can use to negotiate their roadless and trackless raw new world without having to stop to build the traditional road and rail networks. These will come in due time as the initial experimental traffic settles into patterns and volumes that justify their construction.

Aviation - "Ares Aero"

Several promising suggestions have already been made. Several writers have pointed out the possibility of aviation in the thin Martian air. Baseline "sea level" air pressure on Mars is equivalent to that 125,000 feet up (38,000 meters, or 24 miles) here on Earth. A neat trick, but well within the envelope pioneered by a number of experimental aircraft to date. The most challenging aspect of aviation on Mars will be taking off and landing. Without lift-assist, such maneuvers may have to be made at speeds up to 700 mph or 1100 kph. Launch track acceleration might help, but landing at such speeds would present a formidable performance assignment for Firestone or Goodyear.

For this reason, much of the discussion now centers about combination dirigibles and aircraft in which enough of the weight of the craft is neutralized to permit operation at significantly lower speeds. On Mars where there is no free oxygen, certainly not in quantity, to support combustion, designers can specify **hydrogen for buoyancy** with four times the lifting capacity of helium, and far more readily available to the technology of the early settlement.

There is a primer discussion of these possibilities in The Case for Mars II proceedings (1985) pp. 489-96 "Dirigible Airships for Martian Surface Exploration" [AAS 84-176].



Hybrid Mars dirigible aircraft

Thick Delta Wing holds hydrogen gas, is shaped for speed. *M. Clapp*

We strongly encourage space advocates who may also be aeronautical engineers to get involved in this preliminary brainstorming, so that all the potential pathways can be explored. At least at first, settlers would need a family of "lightened" aircraft that could operate with a minimum of ground support, as they did on Earth in the pioneer days of aviation during the Oughts, Teens, and Twenties.

Presumably, such aircraft would have rocket engines (the air is too thin for props except for ultralight drones) be fueled by burning methane and oxygen, both supplied in tanks since oxygen can't be extracted from the air in flight at volume rates anywhere nearly sufficient. Such a fuel will require a substantial ground installation to support each refueling site.

This creates a burden. Either we must develop a compact efficient fuel-processing plant that can be produced in quantity on Mars (or at least the more massive, simple, and most tolerance-forgiving of its components) for drop-off-and turn-on deployment at uncrewed sites. Nuclear or solar power could supply the energy needed.

The alternative is to use an aircraft engine that can run on a fuel that the aircraft can produce with a much smaller and lighter weight power plant on board the craft itself.

NIMF **- Nuclear** rocket using **Indigenous Mars Fuel**

As already reported in MMM # 30 NOV '90 "NIMF" [Available by SASE + 50¢ from MMM Reprints c/o the LRS P.O. Box.] Martin Marietta's Robert Zubrin [a candidate for the NSS Board of Directors] first suggested how a Mars landing craft could refuel itself from the Martian atmosphere with an *on board* power plant and use that fuel to make exploratory sorties to distant sites on the planet. Second he suggested (with the help of illustrations by Martin Marietta artist Robert Murray) two configurations: a ballistic hopper, and a winged shuttlecraft that looks a lot like its currently flying Earth-LEO ancestors Columbia, Discovery, Atlantis, and Endeavor. This craft would use 4 VTOL (Vertical Take Off & Land) engines to allow Harrier-like landings and ascents to and from Mach 1 flight. This avoids what could otherwise be an extremely heavy burden for the early settlements: grading and paving landing strips. Whatever your reaction to the use of nuclear power plants on Mars, this is the most versatile Mars-global transportation system yet suggested, one which can be put into place at the very outset and used to establish scattered sites, not merely support them once established.

Ground Effects Vehicles - the Skimmer

For many exploration and routine transportation needs it would be far more useful to (also) have a swift means of surface, or near-surface, transportation. The two sites we've visited via our Viking proxies have displayed daunting strewn-fields of variably sized boulders. We don't know how typical this is of Mars but our best guess might be "very". This will make the going rough and slow for wheeled vehicles, though several interesting designs are in circulation and a number of contractor and university built prototypes actually field-tested. Many designers have despaired and turned to walking vehicles instead. Whatever the view from the ivory tower, to the explorer and/or settler on Mars, either choice will provide exasperatingly slow, tedious, and patience-testing travel at best. Without going to all the trouble to grade roadways to places we may not want to visit again any time soon, there has to be another way. Mission planners on Earth may not care, but those of us who would earn our place as spiritual ancestors of the actual settlers to follow, should.

Can a Mars hovercraft be built? Remember the air is very thin and even compressing it somewhat under flexible skirts is not likely to produce enough lift to do the trick - unless, that is, we "lighten" the effective marsweight of the vehicle itself by hydrogen-filled buoyancy tanks. Even so, we are left with some interesting challenges. First, whereas traditionally supported ground vehicles can be "loaded up" with fuel and cargo to the fairly generous limits of its suspension system, a Martian "skimmer" which had say 90% of its weight neutralized by hydrogen tanks or ballonets may not be able to operate effectively if it was heavily fueled, or took on an honest load of cargo. A skimmer which can perform well on near-empty once around the parking lot but not at all under real service conditions would be useless. One approach would be to mate extra buoyancy tanks to each cargo container to be loaded and subsequently unloaded. But that still leaves the problem of how to compensate for fuel weight loss while operating. Of course, valving out some of the hydrogen would compensate - and that may be the only ready answer.

Second, supposing that the weight of craft, fuel, passengers, and cargo is say 90% (or whatever the best figure turns out to) hydrogen-neutralized, can it negotiate the usual size range and spacing of the ubi-quitous rocks and boulders?

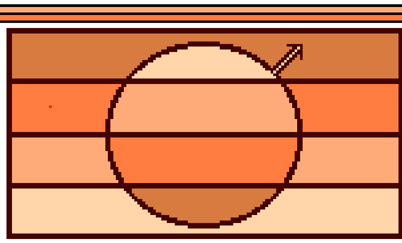
Third, how well can it maneuver? Lightening the weight *does not* reduce the momentum! Our guess is that all of these challenges can be met, once the sofa cushion approach is abandoned. Designing and debugging a Mars skimmer would be a great competitive task for college engineering classes (and fraternity members who may want a diversionary break from elbow-bending), in a design challenge *with a prize,* in an event worth re-running (like the Australian solar-powered car race).

Skimmers could do for Mars what the automobile has done for us - provide cheap on demand mobility. They could be configured as individual/family vehicles, as motor coaches (Martian Greyhounds), and as Trucks (Lorries, if you will). Aircraft will do a lot to help establish Mars as a multi-site world. But only ground vehicles can really make things tick.

Eventually roads *will* be built - at first within the individual towns and outposts, then serving the immediate vicinity, finally linking distant communities. But for a some time in the early frontier decades, it will help a lot if a simpler infrastructure-light means of transportation can be made to work until the infant Martian economy is well enough along on its agenda of growth and diversification to permit the diversion of substantial resources to road- or rail-building and other infrastructure-heavy transportation modes.

If you are a Mars person with technical ability, why not make it a new hobby of yours to tackle some of the above challenges? **<MMM>**

MMM #62 FEBRUARY 1993



A Flag concept for a Future Mars Territory

In the draft at right, the astronomical (and astrological) symbol of Mars (and masculinity), the sphere with upper left arrow, is placed against a color-reversed background with four color bands from a Mars landscape palette: (from light to dark) salmon, peach, burnt orange, and ocher - the arrow in orange-red. - Earth and Mars were at closest mutual approach January 3rd with *Mars Observer* launched last September 16th to arrive on scene next Fall.

Picking Town Sites on Mars:
Climate Considerations

By Peter Kokh

Our first exploration beachhead outpost on Mars is likely to be chosen for purely scientific reasons. What site would would be most conveniently central to the areas of Mars that most pique our geological, geochemical, and archeo-biological interests? Mission planners at NASA, and their purse-string-holding second-guessers in Washington and other participating capitals are unlikely to give a nanosecond's consideration to the needs of the follow-up "permanent settlement" which is the quite different fountain of interest for the great majority of avid Mars supporters.

Not that these two separate lists of attractions don't overlap. They do. Many of the top attractions for prospective Mars geologists (areologists) must also be prominent on any list of must-see tourist attractions. And proximity to certain tourist draws is a strong economic plus for a townsite.

Tourism, however, must be secondary to considerations of economic geography.

√ Where are the most easily accessible resources necessary to support earliest possible self-manufacture of the greatest bulk of the settlement's material needs?

√ What regions offer easiest early-method access to sources of fresh potable water, either from permafrost reserves or "by canal" from the polar ice caps or simply from atmospheric extraction?

√ Where, if anywhere on the planet, do potential prime settlement sites "cluster", affording the least difficult mutual commerce?

√ Are there easily negotiable surface routes to and from an otherwise promising site?

By our read, these considerations ought to be primary if and when a multi-governmental (or para-governmental?) decision is made to follow up human exploration of Mars with its opening as a settlement frontier. Later on, once a number of townsites are established, two considerations will come into play when it comes to the competition between the early Martian Towns for prospective new settlers.

√ Where is the economy booming?

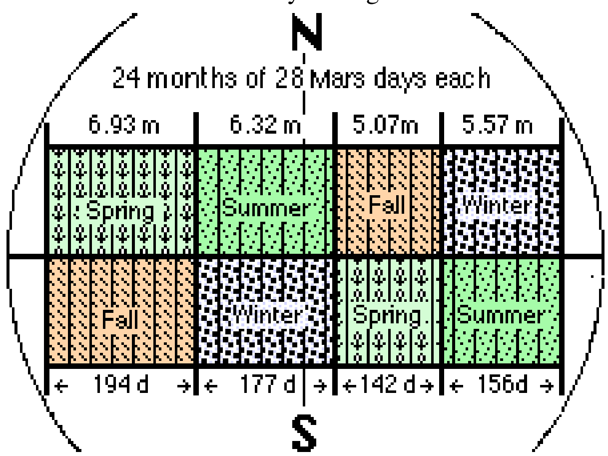
√ Where is the local climate least hostile?

The consideration of climate will become even more important *once* consensus is reached, either before, or after, the opening of Mars to settlement, on the wisest goals and most attractive means to the "terraforming" or "rejuvenaissance" of the planet. While current climate differences between prospective sites may be moot (you can't go outside in shirtsleeves and/or without a mask to bask in the sun *anywhere*) when and if the climate is made to improve some locations might quickly emerge as the "Floridas" and "Hawaiis" of Mars.

To give us some clues to where these future balmy regions may lie, we need first to consider Mars' Season Cycle. The Fourth Planet is tilted on its axis by some 23° 59' relative to the plane of its orbit around the Sun, amazingly similar to Earth's own 23° 27'. Consequently its "temperate" zones have marked seasons, a succession of Winter, Spring, Summer, Fall etc., just as ours do. However the range of temperatures more closely follows that on our own Antarctic Continent, that is, from well under a hundred below Fahrenheit during midwinter nights to a few midsummer early afternoon very localized flirtations with the thaw point.

So just hug the equator, you suggest? Its not as simple as that. While Earth's orbit is mildly eccentric, taking us in as close as 91.4 million miles to the Sun in early January ("perihelion") and out as far as 94.6 million miles from the Sun in early July ("aphelion"), a difference of only 2.8%, Mars' orbit is much more elliptical so that it ranges from 128.5 to 155 million miles out, a difference of near 21%.

Further, neither Mars' winter or summer solstices, nor its vernal (spring) or autumnal equinoxes line up neatly with its perihelion or aphelion dates. The consequence is that the four seasons differ dramatically in length.



MARS' UNEVEN SEASONS: Mars' orbit is very eccentric, swinging out further from the Sun (traveling slower) during Northern Spring and Summer (Southern Fall and Winter) and in closer to the Sun (traveling faster) in Northern Fall and Winter (Southern Spring and Summer). The results are a TRADEOFF.

√ There's more time (13.25 months) to enjoy a cooler Spring and Summer north of the equator, but less time to suffer through a less cold Fall and Winter.

√ There's less time (10.64 m) to enjoy a warmer Spring and Summer in the southern hemisphere, but more time to suffer through a harsher Fall and Winter.

How would these curious facts affect local climates, *and future climatic potential*, of various potential settlement sites? While the terrain may be both more interesting and easier to negotiate from the Martian equator northwards, the warmest midsummer days are likely to occur at low elevation sites (well below Martian "sea level") from the Equator southwards to middle southern latitudes.

Post-Mariner or post-Viking maps of Mars show a large deep impact basin named Hellas Planitia stretching from 29° S to 58° S and from 273° to 312° longitude. Its ramparts lie a couple of kilometers above mean Martian altitude, but the northwest central part of the basin lies as much as 4 kilometers below that mean level. Here, about 38° S lies Mars' equivalent of our "Death Valley". And here, as the atmosphere thickens via human intervention, will it first become possible to bask in the sun outdoors on midsummer afternoons. Hellas is Greek for Greece. The former sea basin *could* live up to its name and host the first "flowering" of "Martian" civilization.

By sheer coincidence, Edgar Rice Burroughs placed his "capital of Barsoom", Greater Helium, in the area of the Hellas basin.

<MMM>

Frontier Republic of MARS

"Fast Track" to "Federal" Autonomy

By Peter Kokh

There is no point beginning settlement if we are not prepared to go all the way.

The "Umbilical" Paradigm Won't Work

Mars ranges 150 to a thousand times as far away from Earth as does the Moon. Launch windows to the Red Planet open every 25 months, rather than daily as with the Moon. Replacements and resupplies must be planned well ahead and generously cachéd on the frontier itself, not in some near-Earth warehouse. In effect, "umbilical cords" connecting the Martian frontier with the home world will not work since they cannot be in continuous service. Instead, a "yolk sack" system of strategic reserve supplies and anticipated next-step development needs to "nurse" the settlements through the long periods of interrupted access will be the approach that works.

As for rescue and relief, much as in that cinema cliff-hanger standby, the suddenly pilotless airplane, "talk through" assistance will be all that Earth, or the equally remote Moon, can routinely offer. Not only day to day decisions, but week to week and month to month ones will have to be made locally without the hollow threat of any veto power from 9 to 34 enforcement-months away.

The upshot is that the demand for effective levels of local settlement autonomy will present itself at a much earlier stage on Mars than on the Moon. This demand will not be merely one of exercising political will. It will be a logical consequence of the remoteness of the frontier. Any sane Earth authority involved in the Opening of Mars will grant such autonomy even *before* the settlers on the scene are quite ready to petition for it, much like a mother bird insistently pushes its hesitant fledglings out of the nest. In this respect, the history of the Mars Colony *should not* follow closely the precedents of previous waves of Earth-bound colonization.

Prerequisites for Autonomy

For the Moon, where logistics allows the "umbilical" approach, it may be possible to simply draw up a list of prerequisites for phase by phase realization of increasing degrees of home rule leading to eventual full sovereignty. These levels may or may not be reached. For Mars, in contrast, it will behoove the authorities on Earth both to relax any "requirements schedule" and work single-mindedly to see that it is met in full as soon as possible.

A plurality of towns offering some measure of economic diversity with interdependence as well as effective occupation of an appreciable sector of the planet with the real opportunity to expand both presence and self-reliance through the combined capacity of the settlements to self-manufacture the bulk of their physical needs should be Aim One. Achieved goals that will enhance settler prospects for a thriving if small "planetization", such as the establishment of a full University, running up a multiyear trade surplus (or yolk-endowment handicap), meeting set population size milestones, successful rearing of a healthy second native-born generation, etc. might be relaxed or waived. Rather, once the infant colony is moving securely on the right track on all fronts, achievement of desired phases can be anticipated and political autonomy granted. This is a real gamble, but it is a gamble that must be taken.

Early Federalism

One settlement a "World" does not make! We have already mentioned the need to have our eggs in several baskets and the need for cultivating the roots of a diversifying inter-dependent economy. Even if the Mars Republic begins with only one functioning local state or province, it will do well to have a federal structure in place. This will help curb later inter-regional territorial disputes, establish a federally administrated regime for yet-to-be-settled areas outside functioning regional economies, and set up patterns by which new areas of the planet can be opened by those seeking to start out fresh, not under the thumb of existing states or provinces.

Isolation of individual towns, even clusters of towns, could be significant. A federal pattern will encourage variety in social, institutional, cultural, infrastructure, and construction lingoes. At the same time state or provincial sovereignty will be limited from the outset and the terrestrial pattern of warring jealously "independent" nation states avoided.

Federal structure will need a regime of federal lands: planetary scenic and geological parks, especially strategic mineral and resource reserves (the ice caps, at least) some of which must be transferred to local state or provincial authority upon the setting up of same, others which would remain federal preserves. The federal government would control off-planet trade, at least, and have title to the moonlets Phobos and Deimos.

To avoid sure conflicts, the establishment of state or provincial boundaries ought to follow some preset guidelines. One, looking forward to a future epoch of terraforming or of the "rejuvenaissance" of Mars, might be the following of clear-cut "divide" lines between potential drainage watersheds. This would establish logical commonalities of future ecological responsibility. [Contemplate how different the political map of Earth would be if on all continents frontiers were those of the great river basins. There would be countries large and small as now, but they'd look quite different from the arbitrarily drawn nation-states we have today.]

Mars should be opened with a chartered Mars Settlement Company already in place. Prospective settlers could buy shares in the Company beforehand, giving them voting rights. A constitution and federal framework covering most of the anticipated pitfall efforts could be agreed upon by all shareholders before the first band of settlers leaves Earth. The alternative is to trust that through on-the-spot conflict resolution, sensible arrangements will spontaneously spring up, with no loss of life, derailment of effort, or resistant residue of ill feeling sure to cause trouble for generations to come. Other things that can be agreed upon by the Company beforehand are official language, frontier legal code, etc.

There is no point beginning settlement if we are not prepared to go all the way. And thus a sensible, well-considered and deliberately pursued plan is *the* way to go. **MMM**

CANALS

On Mars: from Self-Deception to Reality

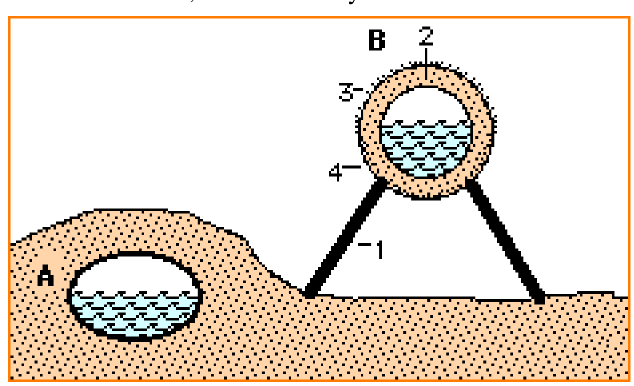
by Peter Kokh

The *"canali"* or 'channels' 'discovered' on Mars during the opposition of 1877, by the Italian astronomer Schiaparelli, and subsequently embraced and promoted as sapient-made watercourse canals by Percival Lowell, were never more than wishful thinking grounded in optical illusion. Supporting evidence of "seasonal" color changes (darkening and thickening "irrigated vegetation" strips between the polar caps and the equator were shown by Carl Sagan to be seasonal redepositions of darker and lighter dust or sand by the prevailing trade winds. The Mariner and Viking probes showed the canals themselves did not exist and that climactic conditions on Mars have been too extreme to allow liquid surface water for a billion years or more. Further, surface-drenching solar ultravi-olet made the vegetation allegedly hugging the canal routes quite impossible.

At the same time a taunting picture emerged of a once water-rich Mars with an ocean, some small seas, great rivers, islands and shorelines. Some of this once generous endowment must remain: in the polar caps, in permafrost, and in possible subterranean reserves. If the canals never existed, the rationale of transporting water equatorwards from the polar caps, now known to be mostly water ice, remains intact: a tempting goal for a future *human* Martian Army Corps of Engineers.

Actual and proposed terrestrial models exist. Water has been rechanneled on Earth by canal and aqueduct for many millennia. And there have been grandiose schemes to do even more on unprecedented scales: Wally Hickel's fresh water pipeline from Alaska to California; proposals to divert Great Lakes water to the arid Southwest; abandoned Soviet schemes to reverse the flow of 3 great Siberian rivers (Ob-Irtysh, Lena, Yenisei) currently emptying into the Arctic Ocean (a scheme sure to trigger a real ice age by increasing the ocean's salinity).

Any logical canal route on Mars would have to follow land contours - valley routes with pump portages over frequent sills in Mars' immature drainage topography. We do not yet possess an adequate topographical map of the planet with accurate elevations. Hopefully, Mars Observer will improve our knowledge here to the point where some candidate routes can be sketched out, for later survey confirmation.

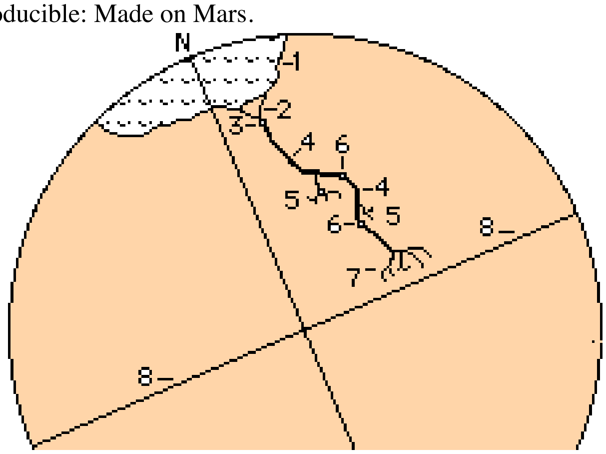


ALTERNATE THERMAL STRATEGIES: In (A), the sealed canal aqueduct is placed in a trench and covered over with shielding soil. But this will only tend to keep it as warm as the surrounding permafrozen soil. In (B), as with the Alaska oil pipeline, the aqueduct is raised over the permafrost from which it is thermally insulated by special nonconductive stilts (1). It is then jacketed by some sort of eutectic thermal mass (2) with its upper surface (3) coated IR-black to passively soak up what little solar heat is available, and its lower surface (4) silvered inward to help retain heat and prevent its radiation toward the cold ground. Here the goal is to use passive solar to keep the jacketing thermal mass just over the freezing point.

While we might romantically choose to call them canals in deference to the shattered dreams of yore, the proposed aqueducts will almost certainly be enclosed to help meet the daunting thermal challenge of keeping the water liquid. It must flow over very long stretches throughout which Antarctic-like temperatures prevail.

The thermal mass could be some ceramic or concrete solid. It could also be some eutectic compound, if a suitable one can be processed from Martian soils, that stores surplus daytime heat by changing phase from solid to liquid, resolidifying as it surrenders that heat when needed at night.

The atmospheric pressurization within the enclosed pipeline could use the available CO2 ambient atmosphere as is, or with additive gasses that help retain heat. The inner surface of the pipe could be coated to be ice-repelling. The freezing point of the water in transit could be lowered by anti-freeze additives if some can be formulated for local manufacture *that can be easily removed* at outflow points to render the water potable again. Could percussion sound waves or microwaves help keep sub-freezing-point water liquid? All the options must be investigated to zero in on those that are workable under Martian conditions, and for which the raw materials needed are locally available, and the components locally producible: Made on Mars.



CANAL ROUTING ON MARS: A number of feeds (2) from the edges of the North Polar Ice Cap (1) could feed into a main pumping station (3). From there, an arterial canal (4) would follow logical land contours on its route southward feeding into a number of mid-course delta diversion areas (5), and crossing passes and divides via pumping stations (6) to a final delta dispersal area (7) in the equatorial regions (8).

Considering that Mars' celestial north pole lies in the constellation Cygnus, the Swan, a few degrees from Deneb, the principal pumping station near the polar cap edge might be colorfully named "Swan Lake". Here the water ballet begins.

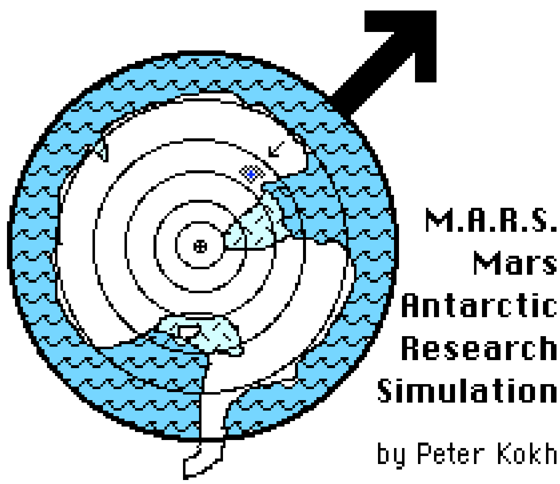
Manufacturing plants (Schiaparelli Manufacturing and Construction Company?) to produce the components needed (pipeline sections of varying diameters and couplings, thermal jacketing material, IR-black coatings, 'silvering', stilts, pump station machinery, etc.) might be best located at some mid-point along the route (5). Settlements would preferentially cluster at (3), (5), (6), and (7). Permafrost water extraction along the arterial (4) could serve as a supplement to usage at mid-course diversion areas (5) with surplus fed into the canal for use 'downstream' (i.e. a cogeneration scheme).

Will more than one such canal be built? That depends on the number of feasible routes and the number of economically attractive townsites each would serve.

Prosaic names could be chosen: the Trans-Utopia Canal, the Chryse-Marineris Canal, etc. There are many who would prefer a fresh start that makes no allusion to the tainted past of runaway Mars speculations. But *why not* dip into the available pool of names from Lowellian canal mythology? Unfounded early public daydreaming aside, Mars will need all the 'romance' we can give it. **<MMM>**

SomeLowellian MartianCanal Names:
Indus, Oxus, Euphrates [also on Earth], Nilosyrtis, Chryse, Phison, Hiddekel, Gehon, Candor, Antæus, Deuteronilus, etc.

Some LowellianNames forCanal-linked "Oases":
Lacus Solis, Phoenicis Lacus, Nuba Lacus, Lunae Lacus, Charontis, Læstygon, Zea Lacus), Ismenius Lacus, etc.



The comparison of Antarctica and Mars has long been made. The ice-bound continent is as close to "another world", one other than our everyday experience, and well off the tracks of common tourist travel, that most humans can ever hope to visit. Beyond its isolation and "difference" are the further similarities of very similar temperature ranges, abundant frozen water, constant winds, and breathtaking trackless scenery.

Beyond that the comparison gets stretched. Antarctic shores are washed by a cold nutrient-rich ocean dense with life. Its shores team with penguins, skuas and seals and occasional other wildlife visitors. And above all, the cold brisk ever-blowing air above the ice is thick, sweet, and breathable.

While there are water-ice sheets on Mars as well - at both poles (the belief that they are composed mostly of carbon dioxide snows and frosts has been long disproved), most of the planet's surface is bone dry, presumably with large expanses of subsurface permafrost of unknown thickness, moisture content, and salinity. Yet here too Antarctica offers a strikingly Mars-similar area in the "Dry Valleys" of the TransAntarctic Moun-tains west of McMurdo Sound, site of the largest human community (if you can call an ever changing collection of single adults a community) in this Southern World.

The Dry Valleys exist because, amidst all this ice, Antarctica, in terms of annual precipitation, is the driest place on Earth. Precipitation has to come from occasional incursions of winds off the ocean, but here the prevailing winds blow everywhere northward from the downdrafts at the pole. In the Dry Valleys there is seldom any precipitation, the march of the ice sheet and glaciers are blocked by mountain ramparts, and the eternal winds are extremely desiccating, enough so to quickly and enduringly mummify any seals, penguins, or skuas unfortunate to wander into the foodless area and die.

Taylor Valley, 2-3 miles wide and 20 miles long is the most accessible, as it reaches down to the Sound. About forty miles inland to the east is 3x6 mile Beacon Valley. To the north of Taylor but approaching no closer than 15 miles to the Sound lies the largest ice free expanse: Wright Valley, connected by dry Bull Pass to 10x18 mi. Victoria Valley. Taylor, Wright, and Victoria all have small frozen lakes and ponds (something the thin air pressure on Mars won't allow).

In these areas - inside surface rocks! and on the beds of the permanently ice covered lakes - lie the most extreme surface or near-surface environments for living creatures on Earth, and amazingly life, be it only microbial, *has* established a stable if shallow and lethargic foothold. Some Mars-Life enthusiasts have been cheered by this and cling to the belief that we might find similar pockets of microbial life on Mars. But that requires a leap of faith, for just because life has encroached there from neighboring areas teeming with it, offers no comfort to those who would think that life could therefore originate in such areas. Nonetheless, the Dry Valleys are a unique natural laboratory in which we can both experiment with techniques to search for life hiding and holding out on Mars, and at the same time gradually develop "Mars-hardy" plants and other creatures from terrestrial stock by a combination of breeding and genetic engineering.

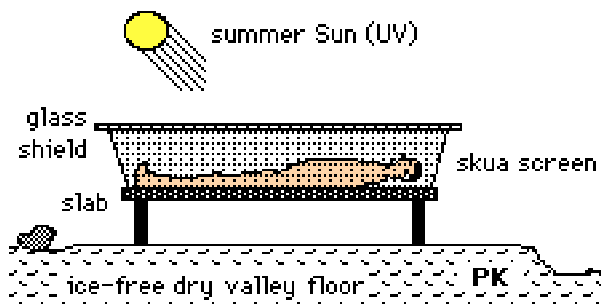
Beyond this immensely useful biological work, some of it no doubt leading to the enrichment of life on Antarctica itself, lie other areas of endeavor by which we can prepare ourselves for the opening of Mars. "Little Mars", if established here, would be the most Marssimilar area on Earth in which to experiment with Mars-appropriate exploration, construction resource-extraction, processing, and manufacturing methods and technologies, allowing us to test concepts for shielding and thermal management as well as debug vehicles that can handle the dry cold. Plans for single habitat outposts as well as more ambitious base-town complexes can be tested.

At "Little Mars", we could test out the "yolk" caché system as a logistics substitution for the "umbilical" support system. Actually we have a head start on this for we currently build up stockpiles of needed provisions and replacement parts in order to allow our various Antarctic bases to get through the winter when the near daily inbound flights from New Zealand and elsewhere are cut off for several long months.

The concept of a "Mars Spring Training Camp" on Antarctica is already beyond the talking stages with strong support from the Planetary Society and the biannual Case for Mars Conference people as well as real, if budget-hamstrung, interest from NASA and the National Science Foundation, the agency running the U.S. Antarctic Program. NSF interest is in improved waste processing and energy production technologies as well as telescience capabilities that may help reduce the number of people needed to run scientific experiments. A pilot program with a teleoperated cable-tethered rover probing the bottom of *Lake Hoare* was set for October-December 1992.

While the concept of commercial enterprise involvement continues to receive no more than the most hypocritical of lip service from NASA - giving the lie to their occasional noises about the desirability of following up initial human Mars exploration with real, committed "for keeps" settlement, "Little Mars" could also serve as an "incubator" for future Martian enterprises. If processing and manufacturing experiments are made, some trial products could be in the form of salable arts and crafts. This would help illustrate the concept of Martian settlers providing for their own needs and developing a uniquely Martian consumer culture of their own. In the process it would help deepen and widen spotty public (and commer-cial!) support for opening Mars. In time perhaps an appreciable part of the continuing operating costs of "Little Mars" could be defrayed in this manner, and this would help to make the base less vulnerable to fickle ever-shifting budgetary whims.

The "Little Mars" concept is worth serious support. While much equipment destined for a Mars effort might better be tested on the Moon, *some* of it will find a more adequate - and much cheaper - testbed in a test site in one of Antarctica's handy Dry Valleys. **<MMM>**

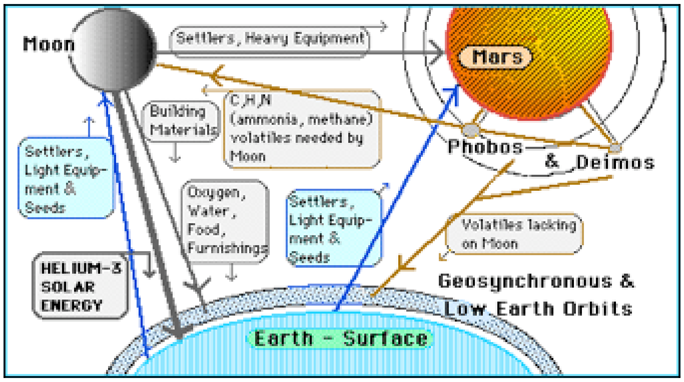


ETERNAL REST IN ANTARCTICA?:

One unusual idea for a cost-defraying enterprise that could be run our of a Little Mars base in one of the **Antarctic Dry Valleys** (perhaps accessible Taylor) is a "Desiccatorium", a place where people could be laid to rest in the open dry frigid air facing the brilliant winter starscapes above, as their modies were allowed to naturally mummify.

Faces and other exposed skin would need to be sun-shielded by UV-opaque glass least the flesh blacken from UV exposure. Screening to ward off scavenger skua birds would have to cover all exposures to the open air.

If people are willing in enough numbers to have their cremated remains placed in an orbital mausoleum-satellite, they would go for this too.



Inner Solar System Trade Routes

By Peter Kokh

The above schematic "map" is one plausible scenario showing the development of trade traffic between Earth, Earth orbit (LEO, Geosynchronous, L4 & L5), the Moon, and Mars and its moons during the early decades after the opening of the space frontier.

Asteroids are not explicitly included in this schema. Asteroidal resources stand to cut into raw materials sales from the Moon, but may hurt sales of volatiles from Phobos and Deimos even more, leaving "Greater Mars" with that much less purchasing power.

The scenario begins with the investment of settlers, capital equipment to process lunar materials and fabricate needed items for local use and export, and seeds. The payback is in building materials, oxygen, water (lunar oxygen probably with terrestrial or PhD hydrogen), and food which can be shipped to LEO and other space outposts more cheaply from the Moon than from Earth because of its high lunar oxygen content. Helium-3 is a potential export of great importance if fusion power is realized.

Lunar raw materials are used in space construction for LEO facilities (space stations, orbital factories to make micro-G products for Earthside markets, and orbiting tourist resorts) and for construction of Solar Power Satellites and the space habitats needed for their construction crews.

The Moon is seriously deficient in hydrogen, carbon, and nitrogen. These elements can be imported to the Moon and to space construction sites more cheaply from Phobos and Deimos than from the deep gravity well of nearby Earth. *If* Phobos and Deimos ("PhD") are relied on rather than Earth-approaching asteroids for this supply, and *if* PhD is regarded as an integral part of the Mars economic area, *then* any profits realized at PhD from this volatile trade can be used to help finance activities on the Martian surface, paying the way for settlers and needed equipment. Lighter capital equipment might come from Earth, heavier items, once they are available "made on Luna", are more cheaply shipped from the Moon.

Every part of this scenario is a current plausibility, given what we now know about the Moon, Mars, Phobos, and Deimos. At the same time, every part of this scenario needs work. We are a long way from listing, let alone designing, the most efficient, lightweight, yet capable complex of capital equipment needed on the Moon to make the best, quickest use of local resources with the least human labor. We only have general ideas how to process lunar materials and what we can make from them. We have yet to plan the best paths of diversification of lunar industry.

We do not know what sort of factories using lunar raw materials can make what sort of marketable micro-G products for Earthside consumption. We have not yet identified the best means either for capturing solar power with cells made of lunar materials or for beaming it down to Earth's surface. Our ideas on how to build things in space like SPS or settlements are sketchy and vague and full of pitfalls.

Nor do we know how we will process PhD materials. Most space supporters think it is NASA's job to put all these pieces of the puzzle together. But guess what? In short, we must collectively get off our butts. **PK**

ICE ⟺ WATER CYCLE ENGINES

Possible engines for Mars Rovers?

By Francis Graham, Editor of *Selenology*
(Quarterly of the American Lunar Society)

The nature of Mars differs markedly from Earth in its having no free oxygen in its atmosphere and shade tempera-tures which are extremely low. As we begin to explore Mars, it is natural that we should select those electromechanical compo-nents with which we are familiar on Earth and which can be adapted for Mars. However, in developing space economies, it would not be unusual to develop mechanisms that would be poorly functional on Earth (if at all) but could well be func-tional on the planet Mars or elsewhere, where the nonterrestrial conditions can be best used. Reflecting on this possibility, one is led to a variety of Mars-specific categories. One such cate-gory is heat engines designed for Mars.

The Ice-Water Cycle Engine

In attempting to choose a design for a heat engine for Mars, the conditions of electrical power from the sun and low temperatures (-75° C, -103° F) were the major ambient factors. The lack of oxygen made internal combustion engines impos-sible [unless the oxygen is provided from an onboard tank]. A steam engine is possible, with a large solar concentrator provi-ding the heat. But on Mars, it is possible to go over to the other phase transition, water⟸⟹ice, with a weight saving over steam pressure fittings and only a small loss of efficiency. A heat engine cycle across the liquidus⟸⟹solidus line using H2O as a working fluid, i.e., an Ice-Water Cycle Engine, offers advantages.

The Ice-Water Cycle Engine is a cylinder filled with water and a piston. When the water freezes, it expands, and work is done against the piston. The solid is then returned to the liquid phase by joule resistance heating. Energy is thus transferred from the solar panels to the atmosphere through a phase transition which also produces work. The greatest advan-tage is the large force on a piston of modest area; the slope of the equilibrium curve is so sharp (dP/dT= -130 atm/K) that enormous forces can be generated by the expanding ice. The limit is reached when higher phases of ice with a specific gravity greater than 1 are produced. Operating between -17° C and 0° C [1.4° to 32° F], 2100 atmospheres (2.1 x 108 pa) can be generated on the piston. This makes the ice-water cycle engine ideal for situations on Mars where crushing, pulver-izing and heavy lifting are desired. It also has a weight saving over electro-inductive/hydraulic systems, especially valuable on automated Mars rovers which must be lifted up from Earth.

A small operating ice-water cycle engine was constructed and tested at the Allegheny OIC**1** technical school in McKeesport, PA during the winters of 1978-79. Piston return was facilitated by a simple oblique spring after melting was performed by an external coil connected to an automobile battery. Cycle times were about 90 minutes**2** depending on the external temperature and the battery was drained rather rapidly. These test were not rigorously scientific but were simply designed to see if the concept worked at all.**3**

Calculation of Engine Efficiency: heat into the engine is - 79.9 cal/g = 333.1 j/g. The work function is generally

$$W = \int V(PT)\, P\, dE(P,T)$$

Considering the upper pressure limit of 2100 atm (2.1 x 108 pa) and the volume change of

$$\Delta V = 0.093 \text{ cc/g} = 9.3 \times 10\text{-}8 \text{ m3/g}$$

Then

$$\int P dV = P \int dV = 19.53 \text{ joules/g}$$

For which the thermal efficiency is

$$\eta = \frac{W_{out}}{Q_{in}} = \frac{19.53}{333.1} = 5.8\%$$

This is comparable to the actual efficiency of a steam engine. Due to thermal gradients, the actual efficiency of an operating ice-water cycle engine will be somewhat lower. Additional controlled experiments are required.

In conclusion, solid/liquid phase heat engines may well become part of a menu of technology useful to applications in space economies. Undoubtedly, many other possibilities on that menu specific to extraterrestrial conditions remain to be discovered. **4** **<FG>**

Footnotes:

1 Opportunities Industrialization Center.

2 In a phone conversation 1/15/93, Graham suggested that this long cycle time could be brought down at least to a few minutes by using an internal heat source, perhaps a laser, in combination with a very heat conductive outer cylinder. The idea of his experiment was just to see if it worked at all, not to optimize the engineering.

3 A rather thorough patent search showed no prior work on this type of device. Graham welcomes hearing from anyone else who has thought or tinkered along similar lines. Write him c/o MMM.

4 Graham also reports on solid-liquid Bismuth engines suitable for use on Mercury. MMM will publish that article separately.

Acknowledgements: The author wished to thank Dale Amon, Hans Moravec, and Norman Wackenhut for fruitful discussions, and the Allegheny OIC for many kindnesses.

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MAILBOX

Letters to kokhmmm@aol.com

Growing the Economic Case for Mars

Your editorial in the February issue of MMM was very challenging. But in the very next issue [March # 63] you gave clues to what just could be a major part of an answer.

Earth is so much more "industrially fertile" a world than the Moon because billions of years of very active water-involved geological processing have concentrated many of the trace elements modern technology has grown dependent upon into ore and mineral veins from which these elements can be extracted rather "economically".

Mars represents an in-between case. Full-blown plate tectonics never developed, witness the magma-hot-spot-stuck shield volcanoes, probably because the once abundant surface water reservoirs disappeared too fast or were too localized (in the northern hemisphere). Yet it is quite evident that considerable rifting has occurred.

At this stage we cannot be confident that any of the element-leaching ore-body-building processes that occurred on Earth also occurred on Mars. But if such processes did operate, even for a short time, there just may be a few scattered lodes of sundry ores of real economic value.

Not only would this be a boon to any future settlers on Mars for their own purposes, it might give them an additional cost-competitive export to the Moon, which is deficient in copper, lead, zinc, tin, gold, silver, platinum, mercury, chlorine, fluorine and the other halogens, germanium, gallium, arsenic, tungsten and other hard-to-do-without elements needed in small amounts. If such treasures could be launched cheaply in processed or crude ore form to Mars orbit, say by a launchtrack up the west slope of mighty Pavonis Mons [MMM # 18 SEP. '88] and then transshipped to the Moon at a cost break over shipments out of Earth's much deeper gravity well, future Martians may find a better way to integrate themselves more thoroughly into a Moon-anchored economy supplying Earth with space-based energy.

Until we can do a thorough orbital chemical mapping of Mars and back this up with ground truth prospecting of promising sites, we can do no more than hope that such geologically-provided mineral concentrations exist. I would prioritize the search in two areas: (1) the craters and slopes and lavatubes of the great shield volcano massifs where any crustal material further processed in the magma might be found and (2) the walls of the crisscrossing canyons of the chaotic labyrinth terrain at the head of the Valles Marineris rift-canyon. These walls might be the best place to see whatever treats lie in the exposed strata

Thomas Heidel, Milwaukee, WI

Developing "Mars-hardy" Plants

More than once you have mentioned the possibility of breeding plant varieties that could survive out in the open on Mars - once the carbon dioxide atmosphere had been thickened somewhat by incipient terraforming activity and temperatures rise seasonally high enough to allow liquid surface waters.

Some research has been done to support the belief that the physiological needs of plants in near-vacuum conditions are less rigorous than those of humans. Some cultivated plants have been known to thrive in vacuum jars with atmospheres as low as 30 Mb [3% Earth normal (1 bar), whereas Mars' atmospheric pressure varies seasonally from 7-10 millibars, 0.7-1.0% Earth normal].

Also the ease with which many plants adapt to higher UV levels at high altitudes suggests that they may be further adaptable. And some succulents and cacti can withstand higher radiation levels than exist in any natural environment on Earth. So the development of radiation-resistant crop strains should at least be possible.

The environment on Mars, even at enhanced pressure levels, will remain highly desiccating and "space-exposed" both to UV and cosmic radiation. This suggests that high altitude succulents, if there are any, may be a good place to start in any attempt to breed "Mars-hardy" vegetation.

Michael Thomas,
Seattle, WA

Lowell's Canals; Ice-Water Cycle Engines

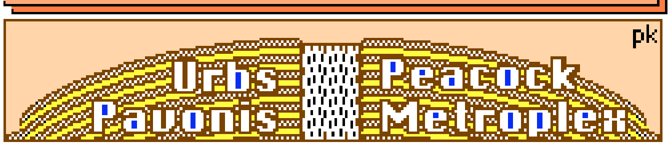
A list of Lowell's canals form Acalandrus to Xanthus (there are 183 of them!) along with a map can be found on pp. 145-6 of Lowell, P., Mars (Longman, Green & Co., London 1896).

Many thanks for publishing my article on Ice-Water Cycle Engines. I don't personally have the resources to engineer prototype space liquid/solid cycle engines or experimental methane-hydrogen sucking jets which carry oxygen. Yet I have felt these ideas should be at least described.

Please let me know if there are any nibbles - supportive or critical on either of these ideas. If an idea has a flaw, I sure want to know that too. Perhaps one of the nibbles will lead to an opportunity to continue this line of research.

Francis Graham,
East Pittsburgh, PA

MMM #73 MARCH 1994



The Site for Mars' Main Settlement

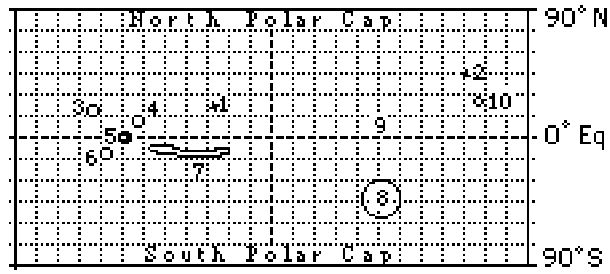
By Peter Kokh with Bryce Walden

Pavonis Mons' Economic Importance as a Launch Site

In MMM #18 SEP '88 pp. 6-7 "PAVONIS MONS: Very possibly the most strategic mountain in the Solar System" [republished in MMM Classic #2.] We (Kokh) made the point that the combination of Pavonis' great height and its position astride Mars' equator destined it to play a major continuing role in the development of any Human Martian frontier.

First its west slope could host a launch track, one far better advantaged than any up remotely similar candidate mountains on Earth: Mt. Cayambe in Ecuador, Mt. Cameroon and Mt. Kenya in Africa, Mt. Kinabalu in NE Borneo. The gentle slope of Pavonis reaches at least three times higher than any of these. Nor are there the torrential west slope rains that plague all the Earth sites mentioned.

Add in the lower gravity that must be overcome, with an escape velocity 38% that of Earth's, and the West Pavonis Launch Track (WPLT) promises to be the export workhorse of the Martian economy. Since once such a launch track is installed, it will make no sense to export from Mars from any other site, Pavonis is likely to be central to a major part of the Martian pioneer settlement population.



A Mercator Projection of MARS with grid lines 15° apart. KEY: 1-2 the two Viking landing sites; 3 Olympus Mons; 4-5-6 the three great Tharsis Ridge shield volcanoes: 4 Ascraeus, **5 Pavonis**, 6 Arsia; 7 the Valles Marineris; 8 Hellas basin; 8 Syrtis Major plain; 10 Elysium Mons

While thanks to its tenuous atmosphere which permits aerobraking, it actually requires less fuel to soft land the same payload on Mars as it does on the Moon, Mars is behind the economic eight ball when it comes to exports *with which to pay for* imports. Volatiles (methane and ammonia, containing precious hydrogen, carbon, and nitrogen; other HCN feedstocks) shipped to the Moon, LEO, and Space Settlements from its moonlets Phobos and Deimos are Mars' one real salable asset. Any manufactures made in the Martian Settlements themselves and intended for export, will either have to be something of very unique value made nowhere else, or find a way to compete on price via dirt cheap launch, i.e. up the *"Pavotrak"*.

(Someday, *if* Deimos can be "nudged" just 1900 miles closer to Mars into a synchronous orbit above Pavonis, and *if* Phobos' orbit can be moved out just 271 miles to cycle three times a Mars day exactly, and given just a little inclination with non-precessing nodes (much the bigger trick), then a Pavonis-Deimos Elevator could be built spanning a distance only 4/9ths as great against a gravity load only 3/8ths as great as a similar elevator on Earth, thus requiring much less exotic materials.)

Pavonis Mons as a Major Settlement Site

What we say here holds true of the other great shield volcanoes on Mars: Olympus, Ascraeus, Arsia, Elysium, etc. But Pavonis' equatorial advantage gives it an enormous edge.

In the previous MMM article sited above, we had also pointed out that the basaltic Pavonian slopes would allow us to build shelter with materials and methods with which we would already be familiar from our lunar experience. It is right here, on the topic of settlement construction, that we want to look at

Pavonis again, and speculate about the "annexation" of this site into the Human-Gaian Diasporal reach.

Enter into play another trump card. Shield volcanoes, like Earth's largest, the Hawaii Big Island Mauna Loa - Mauna Kea complex, are built up of layer upon layer of relatively "runny" (melted tar-like) broad sheets of extremely fluid lava of low silica and gas content and very high temperature (1100°C = 2000°F). This is what gives shield volcanoes their gentle slopes in the 3-5° range (as opposed to the more photogenic classical cone shaped volcanoes like Fuji). Part of the process by which these layers are laid down results in the formation of numerous lavatube conduits. The Big Island is "laced" with them, with 482 now listed and more being formed in each eruption. In the continental U.S. the Medicine Lake Volcano in northern California is another well-studied example.

Ronald Greeley, in his paper "Lava Tubes in the Solar System" (in G. Thomas Rea, Ed., 6th International Symposium on Vulcanospeleology, National Speleological Society, 1992) proposes lavatubes on Mars. In high-resolution images from the Viking Orbiter spacecraft, open channels and roofed channel segments are clearly visible as radial patterns around the summit caldera of Hecates Tholus, a shield volcano more than 200 km across, for example.

"Many of the lava flows that built both the shield volcanoes and the plains [of the Tharsis Ridge] were emplaced through lavatubes and channels. Some volcanoes such as Alba Patera, are enormous structures covering thousands of square kilometers and are composed of individual lava flows fed through extensive tube and channel systems" (p. 226). Greeley does not single out Pavonis Mons. He also says While lunar basalt is enriched in titanium, *some Mars basalts may be komititic flows,* "*magnesium-rich*."

To judge by the cross-section of lunar sinuous rilles which are collapsed lava tubes, lunar tubes are very much larger than those we have found on Earth, perhaps 50-100 times as high and wide and long. This may be due in part to chemical differences in the lava but probably has more to do with both the great volumes and depths of the sheets and with the much lower 1/6th gravity. We might expect Martian lavatubes (gravity 3/8ths Earth standard) to be of intermediate size. Caverns tens of kilometers long and tens of meters wide would be very handy ready-shielded volumes indeed within which to place residential, commercial, industrial and agricultural areas of a major settlement complex.

Unless and until proven differently by a ground expedition, the expectation should be that Pavonis is honeycombed with many thousands of miles of lavatubes. In addition, we can conjecture about the chemical composition of the host terrain on much more solid grounds than we can about other sites on Mars. Therefore we can also plan *now*, a suite of building materials industries based on local resources.

[I had put the question to my friends Bryce Walden and Cheryl York of Oregon L5 (members of the National Speleological Society, the other NSS, and the principals behind the Oregon Moonbase effort in a natural lavatube, outside Bend, of which they game me a royal tour in July of '92.) "What percentage of the volume of a typical shield volcano is void, i.e. lavatube? That is, how large a ready laid out metroplex area might we find within Pavonis?"

Bryce sent back by email a veritable treatise on the subject, carrying his calculations, based on the Medicine Lake example, through some 58 equation steps! All the other sources cited in this article are contributed directly or indirectly by Bryce.]

The Argument from Medicine Lake (Bryce Walden)

Rogers and Rice, in "Geology and Mineralogy of Lava Tube Caves At Medicine Lake Volcano, California, give "over 300 caves" ranging from "short grottos under ten meters long to braided systems nearly ten kilometers long. Passage sizes range from 0.25-meter high crawlways a meter wide to 'dirigible passages' up to 25 meters in diameter." According to the authors, these caves represent 18% of the total lava tube volume originally formed (the others collapsed or were filled; that number is mostly derived from collapse trenches).

Medicine Lake is "a large shield over 33 kilometers in diameter which attains an elevation of 2,417 meters." Interestingly, lavatubes appear to form "in a zone on both the northern and southern flanks at approximately 1,370 meters in elevation ... with 1,250 meters taken to represent the base altitude of the volcano, leaving a net height of the volcano of 1,167 meters.

The average of the cave sizes quoted above is 5 km long with a diameter of 12.75 meter. We (Walden) estimate the actual average cave would be more like 1 km long with a 5 meter diameter. This is the approximate size of each major side of Young's Cave at the Oregon Moonbase, and comparable in size to many caves in Lava Beds National Monument. This yields a volume of a cave cylinder of 19,635 cubic meters per cave or 0.0000196 km3 or a total of 0.00589 km3 of "known" voids for the whole volcano.

Next, we calculate the volume of the volcano to be 332.7 km3, consisting of an upper "shell" volume of about 37.59 km3 including the 150 feet (45.72 m) nearest the surface from which all our evidence is taken, and a 295 km3 "core volume" remnant, to which the argument might be extended.

Of the older caves deeper in the mountain, many will have collapsed or otherwise filled in over time, so this quotient won't hold for the whole volcano. If we estimate the core volcano originally did have a similar void quotient but has been 85% filled in by erosion, collapse, or subsequent flows (Cheryl York thinks this may be pessimistic, perhaps only 50% have been filled, but agrees with using this conservative figure at present), then the void quotient of the core would be 0.00235% and a net void figure for the mountain 0.0128 km3. Please note this is about 13 million cubic meters of void in one small shield volcano. In sum, we might project 0.00386% of the Medicine Lake shield volcano volume is lavatube void with nearly 2 caves per cubic kilometer.

Extending the Argument to Pavonis on Mars

Now Pavonis Mons has a volume 700-1000 times larger than Medicine Lake. (Pavonis is 7 times the diameter of Medicine Lake, covering 50 times the area and is perhaps 15-20 times taller). Taking the smaller figure and extending the same argument, we might expect 10 billion cubic meters involving wider, higher, longer caves spaced further apart. If we postulate an average Martian tube interior ceiling height of 30 meters, that gives us a floor space of about 150 million square meters = 333 square kilometers = 128 square miles, the size of an American central city in the 1,000,000 population range - in a host mountain with a footprint of 40-45,000 square miles, bigger than Iceland and comparable to the size of states like Ohio, Kentucky, Tennessee, Virginia, Mississippi, Louisiana, or New York. (For comparison some other American states in thousands of sq. mi. are: CO 104, OR 96, MN 80, WI 55.)

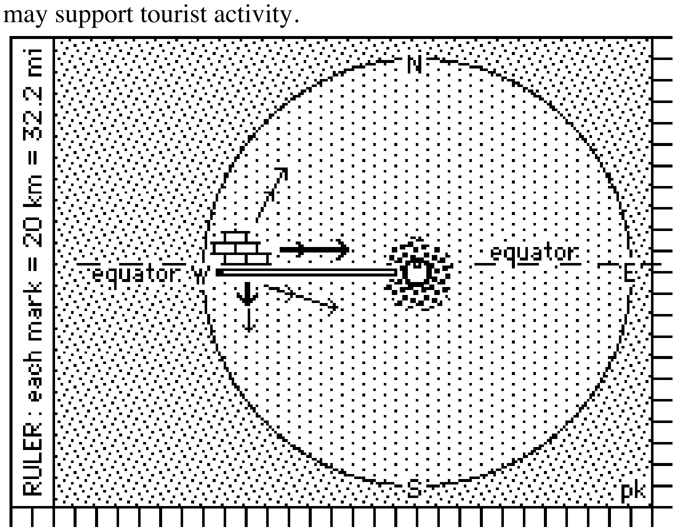
Pavonis (genitive form of Pavo, Latin for Peacock) covers an area about twice that of the BosWash Megapolis with its 40 million people. Since the lavatubes are not cheek by jowl, the potential population of the Peacock Metroplex will be significantly smaller than that. Add in the fact that it has to include within this shielded area support agricultural areas that will perhaps occupy the major fraction of available space (unless this function is taken care of in surface greenhouses - bear in mind that glass protects against UV damage and only seed corn need be protected from radiation.) We still come up with a ready to build-within protected area that can be home someday to tens, perhaps hundreds of thousands of Terro-Martians. As the economy expands to include similar satellite communities in other “Montes” shield volcanoes like Olympus, Ascraeus, Arsia, Elysium, etc., the valcano-hosted urban population of Mars could soar into the millions.

Because these pre-excavated areas are so spread out along the surface of these enormous volcanoes, they are likely to be incorporated as a number of separate communities representing individual tubes or convenient clusters of tubes, all sharing some Metroplex functions in common. We’ll find names like Pavo Heights West, Pavo Cliffs, Caldera Crest, Rim Town, North Peahen, and many others whose names make no reference to the host site at all.

In addition, of course, there will be a scattering of “conventional” surface-trenched towns plying the mineral and other pluses of various sites. We’ll have a better idea of where such specially advantaged spots might be after future robotic missions complete geochemical and altimetric maps of Mars.

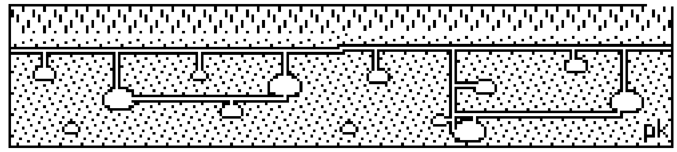
The Pavonis Metroplex Zone

So how might the Peacock Metroplex take shape? We could expect the initial settlement areas to hug the lower end of the Pavotrak launch track complex site and expand as the economy grows and demand arises along the track and around the mountain. Development might leapfrog areas in which lavatubes are relatively sparse or widely spaced to areas where they may be clustered. Some locations might offer enhanced concentrations of volcanic minerals. Sites near the caldera rim may support tourist activity.



Plan of the Pavonis Mons Metroplex Area: The lavatube-riddled shield volcano slopes cover an area about 250 mi. in diameter. The corridor for the launch track up the west face of this equator-straddling mountain is shown, along with the site for a Pavonis-Deimos Elevator Base in the caldera summit. The suggested site for the first settlement is indicated by the brick-pattern area with arrows showing logical directions of early metroplex expansion. Eventually, the entire base of the mountain could be occupied, attaining a population of up to a million citizens or more.

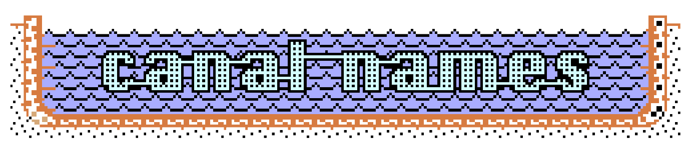
The lavatubes being arranged more or less radially away from the summit, locally they will be arrayed more or less in parallel. Those nearest the surface will be the first to be exploited. This suggests that pressurized cross-connecting roads might best be trenched into the mountain slope surface with access to individual tubes by elevator as illustrated below.



Schema of lavatube habitat areas and their pressurized connectors. (Shown: cross-section of mountain slope perpendicular to radius) Dashes at top indicate mountain slope surface and direction of the summit. Principal “cross-connectors” are most logically trenched and covered at the surface, with access to individual lava tubes by elevator banks. Cross-tunneling only makes sense between major close neighbor tubes and tube systems. Some lavatubes will be “off the beaten path” and by-passed in creation of the Metroplex.

Freight and Passenger traffic are likely to be separated especially in elevators. As to solar access, it will be possible, and more efficient in the long run to pipe in sunlight by mirrored shafts or fiber optic bundles than to use surface-avail-able solar power (just 36-52% as intense as at Earth, depending on the time of Martian year) to produce artificial lighting tied to the sunrise-sunset period above. We might see both, with nearer-surface tubes trying direct access, deeper tubes opting to repeat surface lighting electrically. Either way, it will be more cost effective to faithfully follow the seasonally varying length of daylight than to produce a standardized day-night cycle below.

Pressurizing leaky lunar lavatubes won’t be smart. On Mars where we *want* to alter the given atmosphere over time, we might do just that. Pavonis Mons will be one of the most interesting settlement scenes in the entire Solar System. ***PK***



By Peter Kokh

[A followup on the piece “CANALS on Mars: from self-deception to reality”, in MMM # 62, FEB ‘93 pages 6-7.]

Lowell’s List

Almost all science fiction novels about Mars written prior to the successful Mariner 4 and 9 missions, took the existence of the canals “observed” by Sciaparelli, Lowell, and others as a given. Either they were dust- and weed-choked ruins of a long-vanished native Martian civilization or still working water routes maintained by a handful of native survi-vors. And these writers gave them names from Lowell’s List.

We now know such features to be illusory. Yet it is possible that future Martians tracing ancestry back to Earth will someday build canal-like aquifers to transport water across Mars. These settlers can either choose to start afresh, naming them after prominent natural features along the route - or after the mistress of the construction team boss. But they could just as easily choose to exonerate Lowell's List, thereby infusing the romance of a tradition that predates by several decades the dawn of the Martian Era (1/1/1961 = 1 Gemini 1 m.e.).

Two readers responded to my request for sources of information on the names Lowell and others had given to the lines they honestly thought they were observing. Jeff Sanburg (Skokie IL) wrote that 1908 vintage maps of Lowell's canals are to be found in Willy Ley's classic Mariner IV to Mars. Francis Graham (East Liverpool OH) sent us the complete list, an astonishing 183 names in all. Our thanks to both!

Of these 183, 89 had been "observed" less than ten times. Another 61 had been recorded less than 33 times. That leaves 33 names given to linear phenomena "seen" from 33 to 127 times each. Agathodaemon is the one observed and drawn most frequently. "Earning credit" towards immortalization as names of future human-engineered Martian aqueducts, they are:

Agathodaemon 127	Ambrosia 36	Araxes 93
Bathys 69	Brontes 38	Cambyses 34
Cephisus 35	Cerberus 44	Coprates 41
Corax 33	Daemon 118	Eosphorus 56
Eumenides 103	Euphrates 36	Ganges 82
Gigas 60	Gorgon 33	Hebe 37
Jamuna 39	Laestrygon 41	Nectar 87
Oceanus 37	Orcus 35	Orontes 33
Phison 56	Pyriphlegethon 53	Sirenius 60
Steropes 46	Tartarus 42	Titan 38
Tithonius 78	Typhon 33	Ulysses 33

Alternately, these canal names are available for water-tanker truck routes from the poles to the equatorial regions, even for the trucking firms so involved. ***PK***

MARSCALENDAR

pk

A Tale of Two Calendars

"A Calendar for Mars" by Robert Zubrin
Ad Astra, November/December 1993, pp. 25-7

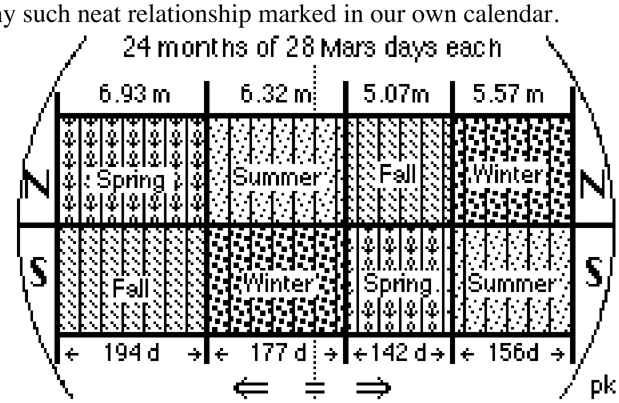
"Mars Calendar" by Peter Kokh
Moon Miners' Manifesto # 19, Oct. 1988, pp. 5-6

Report and Comment by Peter Kokh

Let me begin by saying that I *endorse* Bob Zubrin's Mars Calendar design - with two minor reservations - even though there are aspects of my previous suggestion that *in the abstract* I might prefer. *In the concrete*, Zubrin alone has the name recognition and prestige needed to gain widespread acceptance, perhaps even official adoption, for such a proposal. That would be a coup in the effort to raise public awareness of Mars and of its similarities and contrasts to Earth. These days, Zubrin, as much as anyone, is Mr. Mars.

In the calendar proposal outlined in my earlier article, I began with the goal of preserving the 365-day *like* rotation of holidays and anniversaries with which we are all familiar and comfortable. Mars' orbital period is some 669 Mars days long (690 Earth days), a long period almost commensurate with 2 Earth years (730.5 d). So I thought to divide it into two equal "versaries" (coined from anniversary) of 334.5 Mars days each - per "Zodian", one complete orbit, i.e. pass around the Zodiac. The logical point of division would be not along seasonal lines but between the in-leg (from aphelion, when Mars is furthest from the Sun, to perihelion, when Mars is closest to the Sun) and the out-leg (perihelion back to aphelion) portions of Mars' orbit. While such a duplex calendar would not neatly coincide with the Martian seasons, neither does the common Earth calendar. Earth's year begins not with the first day of spring, which Zubrin's proposal assumes to be the logical point, but at perihelion, on January 1st when Earth is closest to the Sun. (It is cold in the northern hemisphere while we are actually at our closest to the Sun because of the 'overruling' axial tilt of Earth's north pole away from the Sun at that time.)

Next I sought to honor the 28-30 day "monthly" cadence with which we are equally at ease. This means, of course, that when months begin and end can have no neat relationship to the arrival of seasons on Mars. But neither is any such neat relationship marked in our own calendar.



The 28 date months I had proposed would rationalize the traditional 7-day week, the most change resistant temporal rhythm in all human experience. Every month could begin on the same day of the week, *that year*. As the paired 334-, 335-date versaries called for would be together 4 dates longer than 95 weeks, a "Sunday" versary pair (or Mars year) would be followed by Thursday, Monday, Friday, Tuesday, Saturday, and Wednesday years (or by whatever other names the weekdays on Mars might one day be called) in an ever repeating cycle. However, day-date coupling *could* be arranged by placing an eighth "leap day" at the start of each season.

Zubrin's calendar begins the year with the first day of northern Spring (southern Fall). (Historically, Earth's calendar *used to* begin with March - December means literally the 10th month, not the 12th!). With three 'months' per season and 12 per Martian year, it becomes logical to denote them by the zodiacal constellations in which the Sun appears from Mars. [Ed: let's not call them "months", an inappropriate allusion to the Moon, but "**zodes**" ("sign" has a bad connotation).]

The advantage is obvious. Almost everyone, space aware or not (indeed especially the space-ignorant!) already knows the names of all twelve Martian months or zodes!:

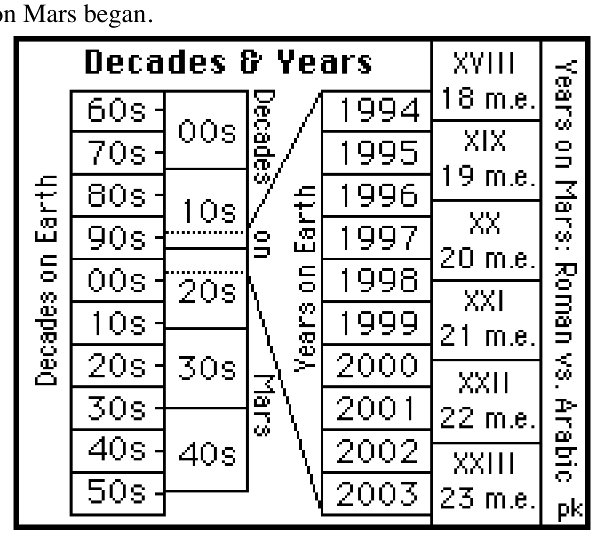
Gemini, Cancer, Leo, Virgo, Libra, Scorpius,
Sagittarius, Capricorn, Aquarius, Pisces, Aries, Taurus

Choosing to enshrine these names into Mars' Calendar will at least superficially lower the threshold of comprehensibility of our dream of settling Mars for the average person on the street. That should not be dismissed as a spurious consideration, if we want someday to *realize* that dream. With the right publicity campaign, more and more people on hearing the name of some zodiacal constellation, will think Mars, not astrological sign.

In the Zubrin proposal, with the months or zodes varying in length from 46 to 66 Martian days or sols (the seasons varying so much in length because of Mars eccentric orbit - its angular motion much faster when nearest the Sun than when farthest) no easy weekday repeat pattern is likely. But again, overall day-date coupling could be arranged by four out-of-week days, perhaps beginning each season: Gemini 1, Virgo 1, Sagittarius 1, and Pisces 1. But Zubrin himself does not discuss the day-date question in his proposal. Perhaps future Martians *might* decide the disorder of our present uncoupled day-date system provides healthy variety. (But is it the wisest choice to thus pacify the eternally warring Friday, Saturday, and Sunday clans of fundamentalism?)

One of the most spirit-lifting appeals of opening new worlds like the Moon, Mars, and Space Settlements is just this opportunity to start over "afresh", to shed the more irrational baggage of history, and choose our cultural infrastructure more wisely, so that the pace of our lives might be more in harmony with the grain of nature. The unaddressed day-date question aside, Zubrin's proposal is a brave attempt to do just this. The 46-66 date long zodiacal months calibrated to Mars' eccentric season patterns and the 88% longer Martian year must establish a new, characteristically Martian feel for time, something that will echo throughout Martian culture. His calendar showcases what is so transcendingly different about Mars, providing an appropriate hanging strip upon which to time-fasten other cultural innovations: holidays, feasts, and rites of passage etc.

On the other hand, Zubrin proposes using Roman numerals to keep track of Martian years, beginning with year I starting when Gemini 1 (on Mars) last coincided with January 1 on Earth in 1961. This *is* a good choice for beginning the Martian Era as it is near the outset of the Space Age and the first probes sent towards Mars, i.e. when human activity near/at/on Mars began.



My point is that the unnecessary choice of Roman numerals, hesitatingly familiar to many, raises an instant barrier of incomprehensibility for many others. Would Dr. Zubrin accept a friendly amendment and use the much more familiar Arabic numerals, perhaps following them with m.e. for Martian Era (e.g. 18 m.e. rather than XVIII)?

Another, equally *nonessential* point of this proposal evoking grave misgivings is that it *chooses* to redefine not just the day and hour on Mars, making them all longer than our familiar periods by a constant factor of 1.0275 (Mars' day 37-some minutes longer than ours) but *also* the minute and the second. This would mean that *no* science textbooks used on Earth could be used *as is* on Mars. But we do not have to use analog clocks. It should be no big deal to devise digital clocks for Mars that incorporate the longer hour and day, but that use the standard second and minute. The Mars' hour would simply advance by one every 61.65 *standard* minutes of 60 *standard* seconds. So I submit this second and last friendly amendment.

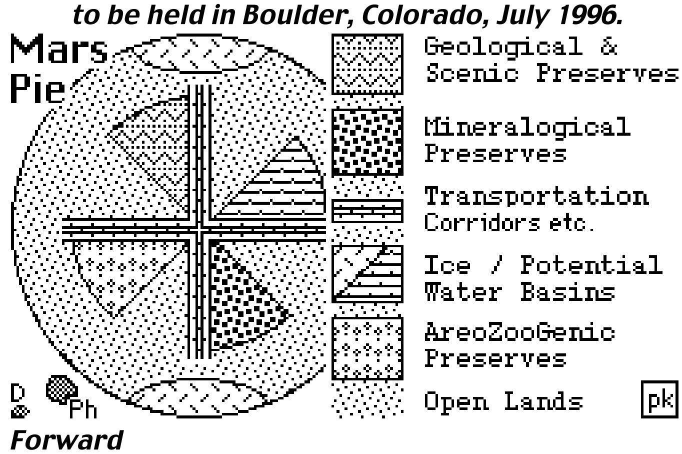
While anything done in advance on Earth can hardly be "binding" on future Martian settlers, adoption of this centerpiece of cultural infrastructure would put into place a tradition-like momentum hard to set aside. The settlers will have more urgent things with which to concern themselves. By adopting a really good Mars calendar *now* we can only help them.

Zubrin includes an "Areogator" to equate Earth dates and Mars dates. While cumbersome, the formula-chain could easily enough be reduced to run with the press of a single function key on a specially designed calculator. Might not the Planetary Society, best positioned to market such a device, contract with a manufacturer to make such a product, thereby increasing the extent and depth of Mars awareness?

Bob's contacts with the Planetary Society are a plus here. If TPS does adopts the Calendar, if ***Ad Astra*** adopts it (it appears that they are so inclined), if science fiction writers adopt it, and if NASA-Russian Mars Mission planners do so - then I think it will prove to be a done deal. Engage! ***PK***

The MARS HERITAGE Zoning Resolution of 20 m.e./1997a.d.

A Proposal to The Case For Mars VI Conference to be held in Boulder, Colorado, July 1996.



Forward

In MMM # 62 FEB '93 "Federal Republic of MARS" p. 5, we spoke of the need for very early home rule for Mars (it's beyond the short range distances within which "umbilical" connections are logistically feasible) and mentioned the logic of setting up a regime of federal reserves to protect the major geological and scenic areas, major known mineral deposits, major known deposits of ice (and possibly of permafrost as well), and the two moonlets: Phobos and Deimos. This would leave the balance of Mars open to settlement and commercial resource development - under the rule of law, of course - while protecting a/the major portion of the planet's special heritage for future generations of human Martians.

National Parks and Monuments

The Geological and Scenic Areas to be preserved as National Geological and/or Scenic Parks and Monuments could be restricted to those treasures identifiable as such from pre-human exploration missions (Mariner, Viking, MESUR, etc.) Other similar treasure spots identified after the era of human visitation has begun, might be put on a list of places which state or provincial or local governments must protect according to set standards. This would be similar to the setup in this country where not all geological and scenic wonders are part of the National Park, Monument, or Forest systems, leaving many undisputed gems within State Park and Forest lands.

There should be provision within the law for future tourist village/center enclaves in such protected areas wherever a tourist market would otherwise arise. On this list would be the great shield volcanoes Olympus, Arsia, and Ascraeus (with Pavonis Mons being a likely major exception - see the article pp. 3ff.); the great Valles Marineris system of canyonlands, and other places of lesser present fame.

National Mineral Endowment Reserves

Currently, we know little of a non-general nature about Mars' mineral endowment and much less about how any such resources are distributed over the face of the globe. It is possibly that future robotic orbiters equipped with gamma ray spectrometers and capable of generating multi-spectral thematic maps will replace current ill-constrained conjecture with knowledge sufficient to trace the outlines of the planet's "Economic Geography" to the point where we can generate a short list of sites well suited for local resource-dependent settlement.

At the same time, without follow-up "ground truth" missions to check out percentages, quality, feasibility of extrac-tion, and other salient make-or-break details, we may not be able to further trim the list for Settlement Site #1. Meanwhile, other considerations may motivate an earlier decision such as proximity to major geological sites, or to logical surface trans-portation corridors, or to other potential sites (site clustering).

While obviously, settlements must have real access to mineral resources, uncontrolled there-is-no-tomorrow extraction can be avoided by federal ownership of the major pre-detected deposits coupled with a system of licensed extraction and settle-ment "enclaves". In the absence of clues detectable from orbit, however, it will be difficult to protect more than a very small portion of Mars' mineral heritage in this way. But at the least, a regime can be put in place that can be extended to cover and husband other endowment-rich areas of the planet later on.

Potential Water Basins and River or Canal Routes

It is clear that the polar ice caps and at least some of their periphery should be within federal preserves. Permafrost areas are another thing. Future robotic orbital missions might possibly locate the major, nearer-surface frozen soil zones. A debate is in order whether any of these should be set-aside areas or not. Certainly there will be many smaller buried ice pockets that escape orbital detection, either because they are too small, their water content is economically marginal, or they lie too deep below the surface. These, at least, should be up for grabs.

But if someday we are to "terraform" Mars, or better and more naturally, "restore" or "rejuvenate" the planet to its previous more benign condition, then at least some low-lying areas are potential future lakes and seas. Our current altimetric knowledge of the planet is largely conjectured. Future planned missions will give us a map from which we can identify and rank potential catch-basins and even early "immature" water drainage routes. (Mars Observor would have done this.) As to the latter, a little bit of engineering here and there can prod hesitant drainage routes into more desirable paths. Even now, while the area of climate change on Mars is well beyond our horizon, we ought to be able to get enough of a handle on the possibilities to zone aside some areas as likely future basins and riverways, *making sure all early settlements are on "high ground"*. We don't need to repeat the stupidity of shore/flood-plain development that is so rampantly entrenched on Earth.

AreoZooGenic Reservations – AZGRs

Just as far off perhaps is the day when Mars' CO2-rich atmosphere has thickened enough to permit drip-irrigated outdoor surface plantations of specially bioengineered "Mars hardy" trees and other plants. In advance of that day, it may soon be possible to identify favorable "fertile soil" areas, separate from other types of preserves, that might be at least partially protected as potential future National Forest lands, in so called AreoZooGenic Reservations, AZGRs (*Ares* is Greek for Mars).

Much more remote is the possibility of outdoor wild-life on Mars. Vegetation can handle a CO2-rich, O2-stingy atmosphere, if it is thick enough (perhaps ten times the present value on Mars of near a hundredth Earth normal). So the idea of setting aside areas, *other than* the AZGRs just mentioned, as "future Wildlife Refuges" has little merit and no urgency.

Air/Space/Surface Transport Hub/Corridor Preserves

Land Grants to Infrastructure Concessioners

On Earth, at least in this nation's past, designation of railroad and highway corridors and associated land grants have played a major role in opening up the American West to settle-ment and in largely confining it within certain stripes and pockets. It may be wise to consider something similar for Mars. It will be difficult to plan anything logical along such lines, however, until we have a clearer idea of the likely modes of surface and point-to-point transport on Mars.

Air transport, even in the thin air of today's Mars, is a recognized possibility, especially with hydrogen bag buoyancy assist. Airport areas both for VTOL vehicles and those needing *very* long runways are logical set-asides in potential settlement areas offering major identifiable assets or advantages.

What about highways? What about Mag-lev or other railway routes? Given the altimetric data that should be forth-coming from already budgeted missions, it should be possible to identify a logical circum-planetary near-equatorial surface route, and even the major local route options (“the Polodona”, to borrow E.R. Burroughs’ name for Barsoom’s equator). Logical spurs to other interesting or economically promising temperate or arctic areas could also be “designated”. Where the route offers wide leeway, protection need be of only the most general kind. But where it is constricted, e.g. mountain passes, or narrow valleys, specific land reservations may be in order.

Federal and Provincial Open Lands

Settlement sites and even old-fashioned individual and communal homesteading might be liberally permitted outside the Federal Land Reserves suggested above. Permits, of course, ought to be granted on the basis of some minimum set of demonstrated assets and capabilities lest the Mars Republic wind up with a lot of mini-communes on the public dole. Make no mistake about it, atmosphere, ice, and perma-frost notwith-standing, Mars will be *only slightly less harsh a mistress* than the Moon. Until some far off age of planet-wide climactic engineering, each community or isolated homestead will have to subsist outside the context of a given all-cradling biosphere, having instead to provide a minibiosphere of its own.

Prime sites for settlements engaged in mining and manufacturing and/or tourism are along the boundaries of the geological, mineralogical, scenic, ice/permafrost, and transport corridor reserves. (Tourism is likely to be a rather low income earner for a long time to come - until either Mars’ population has reached some critical mass, or Earth-Mars passenger trans-port costs and times have fallen some orders of magnitude.)

If state or province boundaries must, by prior law, be established insofar as feasible to follow potential watershed *divides* (*not* potential river courses which only balkanize such watersheds!), there will be put in place *a complementary tool* to help serve shared environmental interests and responsibility. All these features, outlined above, can be adopted within the next decade or two, prior to the first human visits to Mars. The settlers do not need the pain and tribulation of a “Wild, Wild, Lawless Frontier” - they will have hard enough a time without all of that. Suitable amendments can come later. ***PK***

MMM # 83 MARCH 1995

RURAL MARS

By Peter Kokh

RELEVANT BACK READING: MMM #62, FEB ‘93
Picking Town Sites on Mars: Climate Considerations p 4
Mars Frontier Republic: Fast track to federal autonomy p 5
Canals on Mars: from self-deception to reality p.6
[Republished in MMM Classics #7]

Conditions and challenges facing those wanting to live outside the settlements and main “built up” areas of Mars will be significantly easier than those facing their counterparts on the Moon. For one, nuclear powered* compact and modular “air products plants” or atmospheric refineries will provide a steady resupply of oxygen, nitrogen, water, and hydrogen, as well as carbon monoxide and methane for fuel. [Graphite powder or Dinitrogen Pentoxide for air-derived shielding is another possibility. [“Mars Igloos”, MMM #42, FEB ‘91, pp. 4-6. >> pp. 24-26 above] In many locations, a more generous supply of water and derived hydrogen and oxygen could be produced by permafrost taps.

Like it or not, compact **Nuclear** reactors will be far more efficient and attractive than solar power generators on colder, more distant Mars. After all, the Sun itself is a “nuke”. Hopefully, (a) waste disposal problems will long since have been solved, and (b) prospective Martian settlers will be less susceptible to emotional sidetracking than today’s terrestrial population.

Geothermal sources of energy on Mars are a total unknown, and unlikely to exist. Mars has been tectonically inactive for too long a time. Future orbital mappers may find hot spot clues.

Wind power will work only for extremely light loads.

Solar will play a role, but mostly a backup one, just the reverse of the likely situation on the Moon. This is so not because the density of sunlight is too low at Mars, but because of the periodic blanketing of the planet by global dust storms lasting months at a time.

Further, the presence of a thin atmosphere will make inter outpost travel and traffic in goods easier, by **airships and hovercraft** skimmers.

Further, as Mars is geologically more evolved and certain to be mineralogically more diversified than the Moon, prime mining locations will be more abundant, and easier to work. As to serving the tourist trade, sites abound that offer breathtaking canyonland, begging for a hotel or two.

Some interesting observations can be made:

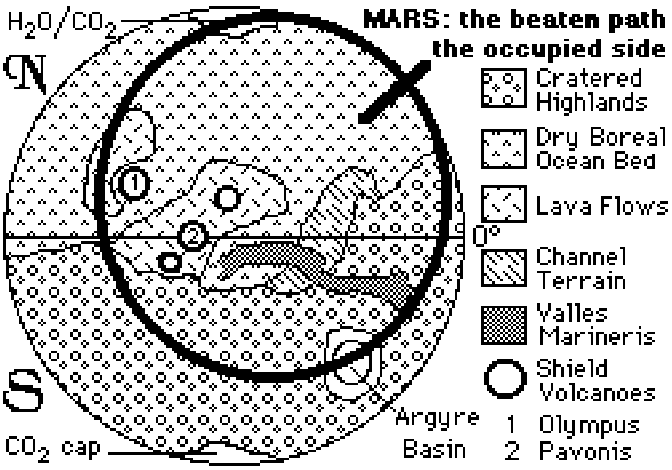
Vehicles: As in Siberia, vehicle windows will be thermopanes. The outer pane needs to be impact resistant against tire-thrown pebbles and rocks, abrasion resistant against dust storms, and UV blocking. Vehicles will need carefully designed dust farings or be “dustlined” [contrast with our “streamlining”] much as on the Moon, but perhaps more thoroughly. They will probably be capable of running on alternate fuels: hydrogen, carbon monoxide, and methane, along with fuel cell backups.

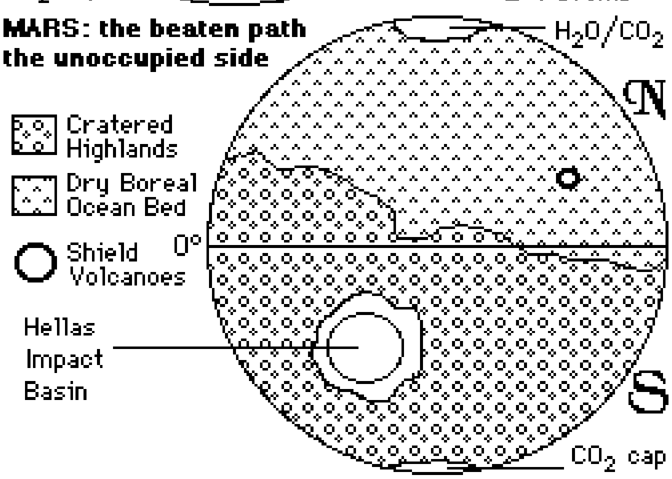
Radio is unlikely without an uninterrupted chain of line-of-sight relay stations along each route. If a network of global communications satellites and global positioning satellites (GPS) proves too expensive for the Mars Frontier Authority to purchase, install, or maintain, “meteorburst” communications, in use on Earth by some trucking firms, may prove just as workable and practical on Mars as well.

“The Beaten Path” will include canal or aqueduct routes form the water-ice cap at the North Pole southward to the tropics, routes between major mining and manufacturing settlements and major spaceport facilities. Sooner or later Pavonis Mons astride the equator will become one of the latter. The same or other routes will provide for one or more tourist sightseeing itineraries through National Geological Parks, showcasing the great canyons and shield volcanoes.

As the Martian economy diversifies and becomes more self-sufficient, so will the interdependence of various towns increase, each producing their own contribution to the list of available items. This network of settlements could well cluster on one hemisphere of the planet for some time. Mars does not have a lunar like polarization of nearside and farside real estate assets. The Pavonis Mons super spaceport site is handy to the other shield volcanoes of the Tharsis Ridge and to Valles Marineris and tributary canyonland attractions. Those potential mining sites and permafrost taps clustering this complex of real estate assets is likely to be sufficient to soak up all development energy and capital for some time to come. Completing a triangular Mars development area will be canal/ aqueduct routes from the North Polar Ice Cap

Rural outposts on Mars will have much greater independence as far as such basics of life as volatiles are concerned. Nonetheless, they will be as or more interdependent on one another for other goods and economic necessities. The Martian "outback" will be more like the Australian, the Alaskan, the Siberian, and the Patagonian, than the barren reaches of the Moon. It'll be interesting all the same.





"The human race shouldn't have all its eggs in one basket, or on one planet. Let's hope we can avoid dropping the basket until we have spread the load."

-- Stephen Hawking

searching for OLD LIFE on Mars

Two different questions - Two different searches

By Peter Kokh

<u>Question 1</u>: What kinds of life forms may have had time to evolve on Mars before irreversible climactic decay, and could any fossil traces still endure?

Mars, it is now generally believed, had a much more benign climate in the first quarter or so of its existence. For perhaps as much as a billion years after it had settled down from the throes of its formation, Mars' young atmosphere was relatively thick. It was warm enough for liquid water to pool on the surface - a whole ocean of it in fact, in the northern hemisphere. We can see shoreline traces even now.

Time changed all that. The orbit changed along with the tilt of the planet's axis with the result that Mars received less solar warmth, year in and year out. The planet's gravity only three eighths that of Earth, its atmosphere slowly and irretrievably leaked out into space with further chilling and desiccating effect. The Sun's friendly warmth was replaced by a different kind of fire, the wrath of an ultraviolet flood.

But consider the glory years, the eon or so in which, *if* life did in fact find a niche in which to begin, it may have enjoyed a crescendo of sorts. How far might evolution have carried *Areoa* (to coin a name like *Gaia*) before retreat set in?

We have only one known biosphere upon which to base our inferences, our own. What kinds of creatures appeared in *Gaia*'s first billion years? Most of us will not find the answer exciting. No mammals, not even a shrew. No birds, not even a kiwi. No reptiles, not even a lizard. No amphibians, not even a tadpole. No insects, not even a gnat. No trees, not even a bush. No fields of grain, not even a crab grass. No flowers, no fruit, no nuts, no seeds. No ferns or fungi, not even a moss or a mushroom.

At sea there were no fish, not even a lamprey - no vertebrates at all. Nor any soft-bodied mollusks, not even a slug. No crabs or clams, not even a limpet. No starfish nor jellyfish, not even a hydra. No tube worms or earthworms, not even a nematode. No anemones, not even a sponge. Hard as it may seem to believe, *no multi-cellular life appeared on Earth until the planet was almost four billion years old.*

There *were* viruses, then bacteria, then one-celled organisms like amoeba, algae, and paramecia. But the more interesting of these did not appear until much after that first billion years. It took a lot of breakthroughs, a lot of genetic and physiological invention, to progress from virus to bacteria. It took even more to produce one-celled organisms.

Fossils? There would have been no creatures with bones. It is just plausible that some organisms had glassy or calcareous spicules. Singly, it would be all but impossible to find traces of their remains. But one could hope to find relics of the oozes which formed from the rain of the inedible parts of dead organisms upon the ocean floor. Fossil traces of algal mats (stromalites) have been positively identified along Earth's ancient shores. And perhaps that is all we could hope to find.

Bits and pieces of DNA? Forget Jurassic park. There were no trees to drip amber sap. There were no mosquitoes to get entrapped therein. Chances are that if we find indications of past life, they will be no more than that, "indications", and we will not be able to reconstruct much of a picture of how such Areoan life resembled, or differed from Gaian parallels.

<u>Question 2:</u> Could some anemic relic of a once far richer Martian Biosphere still subsist in "oases" here and there?

Life can evolve to survive, even thrive, in places in which it could never originate in the first place. There are plenty of terrestrial examples: hot springs; the tundra; high mountain tops; deserts; parasitically or even symbiotically on or within other creatures; in oxygen deprived anaerobic conditions in ocean bottom oozes.

In recent years we have found whole new jungles of life whose food chains begin not with photosynthesis but with methane-eating bacteria (methanogens) like those thriving anaerobically in bottom oozes. These oases surround thermal hot vents in volcanically active mid-ocean ridges in the perpetually dark abyss. Yet, these ecosystems are clearly derivative, all of their species related to ones part of photosynthetic food chains. They could not have independently originated there.

There are perhaps a few places on Mars where life, once established under more favorable conditions no longer the case, might have gradually developed the hardiness to continue to subsist, if not thrive, as conditions inexorably got less and less friendly, eventually downright hostile. Yet it is a romantic notion. As a rule, species die out when their friendly habitat disappears, even if it does so ever so gradually.

The idea of finding "a" life form (i.e. one and only one species) on Mars is absurd, however good copy it might make. We will either find a functional ecosystem consisting of a number of interdependent species linked in complex food chains, or we will find nothing. This compounds the fragility and vulnerability of species to climactic disaster.

Prior to the Mariner and Viking probes, many writers commonly spoke of lichens as the kind of hardy rudimentary plant life that we might just find on Mars. Actually, a lichen is a highly evolved composite plant in which a fungus and an algae live in symbiosis. Neither could survive in their tundra habitats alone. That is a clear indication that they had to arise under more benign conditions. Yet the arctic tundra is far more friendly than any clime we will find on Mars. Its temperature range, atmospheric pressure levels, and availability of seasonal liquid water would make it seem a tropical paradise on Mars.

If we do find existing ("subsisting" is a better term) life on Mars, it is most likely to be microbial. Not only is it apt to be microscopic, it is certain to be reclusive, hiding from the intense naked tissue-destroying protein-busting ultraviolet rays of the Sun, as well as from the extremes of weather, in subsurface areas of rocks and boulders. Scattered about the Martian landscapes in "strewn fields", the bigger rocks and boulders soak up the solar warmth during the day, and serve as heat reservoirs for a time even after sunset, little microclimes each unto themselves.

Such organisms could avoid the nightly freeze in the Summer if their protoplasm contained enough glycol (as many Antarctic organisms do on Earth), but then would surely freeze through as Fall sets in to stay frozen for most of Mars' year. Their own life and reproductive cycles would have had to have successfully adapted to such a regimen. There are plenty of examples of organisms on Earth that wait out unexpectedly long periods of cold and/or drought and successfully revive months, years, even centuries later. Even we humans are used to rhythms: the seasons affect how we provide ourselves with food on an uninterrupted basis. And every night we each commonly "shut down" in sleep, only to "revive" the next day. And we repeat these cycles over and over. *Life does not need conditions that are constantly favorable, only cyclically so, in a dependable way.*

Rock-dwelling microbes on Mars may amount to no more than fiction, but we *have* found their counterpart on Earth, in Antarctica. If they "once upon a time" evolved on Mars, they might have spread around the planet, from rock to rock in sand storms, much as many terrestrial plants rely on the wind to help propagate themselves.

There may be many species of such microbes, some with merely anecdotal differences, others specially adapted to rocks of differing chemical and mineral composition. If we find them, these micro-Martians will provide a delightful and long-lasting high to exo-biologists, but will quickly bore the Hades out of the rest of us.

Implications for Martian Settlement Dreams

No matter what the scientists find, or fail to find, the hoi polloi being as ill-informed as they are, it'll be a simple matter for a few to rabblerouse the public at large into seeing to it that our government(s) make(s) Mars a protected planet, off limits to our bad news species, lest we disturb these little beasties, actual or mythical, and their environment.

Actually, almost nothing we could do is likely to disturb them, uproot them, or supplant them. Earth life, even terrestrial microbes, are ill-adapted to Martian conditions, and are extremely unlikely to survive long enough in the Martian "wild" to threaten the native denizens in any way. And vice versa. Martian bacteria are likely to find the conditions within human habitats intolerable, and die before they could begin to wreck havoc. Alas, the public has read and seen too much scare-fiction. Andromeda Strain and all that. If we find life on Mars, we would be pioneers are dead! Not from Martian germ-life itself, but from our own Halloween fears.

A prayer: *Dear Lord, let the exo-biologists get their thrills somewhere else, like in Europa's ice-encased global ocean. Let Mars be sterile, or dead. Fossil life, okay. But nothing living, please!*

Of course, Mars will be what Mars is! We must look, because we are by essence curious animals. What is to be feared the most is that we will find nothing, but that tabloid-fed rumors to the contrary of a cover up conspiracy will persist. The outcome, a treaty to quarantine Mars, could be the same. The masses need such fodder for their entertainment; Tabloids need it to keep up their circulation. And politicians can't tell the difference. It never gets any better.

The way around such an outcome, of course, is the venerable *fait accompli*. Settlers, defying the proclamations of terrestrial governments, open up Mars anyway - *if* economic incentives for them to do so can be found. No one *now* knows what these economic foundations might be. Today, the outcome of tomorrow's efforts remain uncertain.

Humans, *and Gaia,* will inherit *clear title* to Mars (and that is what we need if age old science-fiction dreams are ever to become reality!) *only if t*here never has been life on Mars, *or if* any and every form of it is now forever extinct. If the latter is the case, scientists might still learn something enlightening from lingering fossil traces. Fossil-laden areas would appropriately be set aside in Paleo-areo-zoic Reserves.

But the stubbornly persistent romantic notion that if we were to find extant native life on Mars, that it would provide the start, at least, of a food chain to support human settlement, and thereby make Mars that much more attractive to the powers that be, the ones in charge of the purse strings - this is notion is unredeemingly sheer nonsense!

Whatever its past, Mars today is a very "raw" world. We can't just heat it up in some metaphoric microwave. We can't just recook it. We need to start with a whole new recipe, with new ingredients. Our cuisine will be Gaian, not Areoan.

The future history of humanity and Gaia on Mars, will not be a continuation of some interrupted past chapter. It will necessarily be a fresh beginning. All the same we must be humbly and reverently mindful of what may have gone before.

As space advocates, we have to set an example in letting go of the wistful daydreams of the past and in bravely rerooting ourselves in reality. MMM

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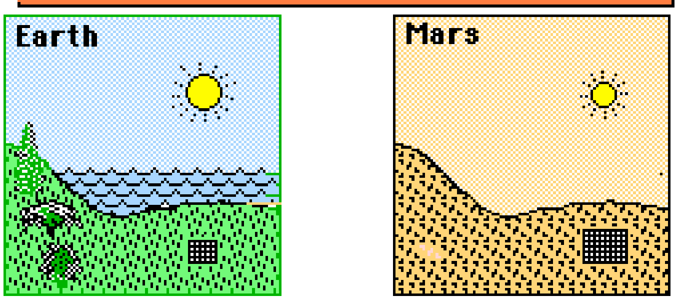


By the light of a smaller, dimmer, cooler Sun

⇐ LEFT: **On Earth**, the Sun shines bright and warm. Our generous oceans act as a thermal sink for that heat, providing an additional mean boost of some 50˚ F (28˚C) over where we'd be without them. Solar collectors do not have to be overly large to tap this energy further.

⇒ RIGHT: **On Mars**, the Sun is noticeably smaller, less brilliant. The radiant heat it sheds is not enough to warm living things, or people. With no ocean heat sink, it is far colder than its greater distance from the Sun would indicate. Solar collectors have to be much larger in size.

IN FOCUS *Mars will require a hardier breed of pioneer*

Many people envision with enthusiasm an eventual wholesale settlement and colonization of Mars, and I number myself among them. In doing so, we carry forward what has become a racial dream of our species throughout this century. And we have done so, stubbornly, through revolution after revolution in our perceptions about the Red Planet. Banished to the realm of myth are the Mars of Edgar Rice Burroughs, populated by green men and princesses and thoats, and the Mars of Percival Lowell, crisscrossed with canals feeding green strips of irrigated vegetation, defying the creeping desiccation of the Planet. But gone too is the glimpse of a moonlike Mars that we read into the photos from early Mariner orbiters.

We know now that Mars *was* once *warmer*, *wet* with ocean, rains, and rivers, and lakes, and possibly in early stages of greening. We are all but certain that much of that watery endowment yet remains, locked up in permafrost layers of soil in lower lying basin lands. There may even be liquid subterranean lakes *if* there are near-surface geothermal pockets still simmering here and there, but we do not know. As to the polar caps, we now know that under a few inches of carbon dioxide frost seasonally chilled out of the atmosphere, there are vast polar ice sheets hundreds of meters thick, at least in the north.

How much water is there? That is, how extensive and patchy are the permafrost deposits? How thick are they? How fresh or brinish? All these questions must be answered to a first approximation accurate to an order of magnitude before any brainstorming schemes of "terraforming" (or, as we would prefer, of "rejuvenaissance" i.e. not making Mars *like Earth*, but bringing it back to the more encradling *Mars-state* it once enjoyed) can be much more than an exercise in "garbage in, garbage out." Which is why MMM has never gotten into such schemes. It is far too premature an exercise.

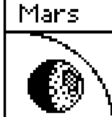
What does remain is the promise of a world that *is* more thoroughly endowed with prerequisites to support human and Earth life than is our own bondsworld, the Moon. Mars would seem to have far more appeal as a homesteading destina-tion for those with enough of the right stuff to be willing to forever forsake the Green Hills of Earth.

But we can indulge in these fantasies, these declarations of willingness to go, only because the need to take a second look has not been thrust upon us by any immanent opportunity to open this frontier. That point of truth is still over the time horizon by an unknown number of years.

When that time does come and those who've thought themselves ready to go are faced with the decision to "put up or shut up", we think that many, even most, will get cold feet.

For despite Mars' life-supportive endowments, the challenges and obstacles to the establishment of a long-term human population capable of first enduring, then of thrivingly coming into its own, are daunting. And they are daunting from many points of view: engineering, logistical, biospheric, but above all and most critically, personal.

It is this last but ultimately most make-or-break class of challenges that we want to discuss here. POINT: Mars is farther from Earth than the Moon, *much* farther. And the implications are *compounded*.

Size: (Earth) Moon Mars	Dist. from Earth (Mn=1)	Dist. from Sun (E=1)	Heat & Power from Sun (E=1)	Launch Window Resupply Frequency	One way transit times
	1	1	1	daily	1-3 days
	150 to 1,060x	1.38 min 1.67 max	52% max 36% min	every 25 months	6-9 months

Resupply, reinforcement, relief, and *rescue* are always from 6 months to 25 months away. This will mean a reliance on a strategic "egg yolk" policy, as opposed to maintenance of "umbilical" style logistics. On site repair and fabrication shops as well as hospitals, both as to equipment and personnel expertise will need to be very much more complete. **Triage** in medical emergencies *will have to be accepted by all* as a potential *personal consequence* before leaving Earth.

It will mean that the personal commitment to the Mars frontier of each pioneer recruit must be individually that much deeper, more "final", that much less open to reconsideration down the line. It will be much more expensive to return to Earth, and the delay time before such a repatriation can be affected will be much, much longer. Only the hardiest, most self-reliant, and resilient personalities should tempt such odds.

Felt isolation from the mainstream of human civilization will be much deeper. Electronic communication with Earth involve response delays of 6-44 minutes, not the 2 plus seconds Lunans will experience. While, in all but live radio communi-cations, those delays can be edited out, the edited conversations will flow jerkily and clumsily. The new "Martians" will tend to turn inward culturally and socially, and go their own way.

POINT: The Sun is not only further, dimmer, and much less warming, it *is noticeably so to the naked eye*. Not all of that is bad, of course. On Earth, full sunlight is uncomfortably intense. On Mars the *softer* light will be still plenty bright enough, and welcome, much as the softly sunny November skies in the northern United States and Canada.

But the smaller Sun [see artwork on page 48] will be a constant reminder of the reliefless cycle of very cool and bitterly cold seasons. Martian summers are but caricatures of our own temperate zone warm seasons, not even quite on a thermal par with the patchy thaws of our Antarctic summers.

The new Martians will learn to cope and grow to find much pleasure and satisfaction in the accommodations they need to make to acculturate themselves to this new world. But only those with the inner strength and drive to make the enormous adjustments had better set out on such a venture.

It can best be summed up so. Only a tiny fraction of the numbers who say they would go to Mars had they but the chance to do so, would also be as willing to commit to pioneering the relatively far friendlier fringes of our own Antarctica, with its vast fresh water supplies, breathable sweet air, and surrounding oceans teaming with life and food. That has to tell us something. *We are all too romantic about Mars!*

Yet as long as the moment of truth reality check is yet far off, we can afford to indulge our Martian illusions. And perhaps that is *good in the long run*. For it carries forth the dream, and with it the ongoing brainstorming exercises that will *one day overcome* the daunting odds. ***PK***

Good Reading on Mars

Astronomy Magazine, December 1995 issue, pages 36-43
"The Mars that Never Was" by Edmund A. Fortier,
Paintings by Chesley Bonestel.

The cure for boredom is curiosity.
There is no cure for curiosity
- Ellen Parr

< MMM's "Platform for Mars" >

⇒ Economic interdependence of several distinct mutually-trading off-Earth settlement communities is the only plausible path to viability of any of them.

⇒ The opening of Mars, its moons, Deimos and Phobos, along with access to near Earth and Main Belt asteroids, is vital to the long-term survival prospects of any pioneer industrial and exporting settlement on the Moon.

To this end, MMM sees the following developments as part of "the critical path"

⇒ **Mars Permafrost Explorer** — The opportunity to pre-test such a probe in Earth orbit to improve our knowledge of terrestrial tundra resources, makes this an easy sell.

⇒ **Ground Truth Permafrost Tappers** — Orbital surveys will not be much good unless calibrated by well-scattered on site drill cores. Further, only by actual on site taps can we tell either the percentage of water content or its freshness or salinity or how we can best tap the deposit.

⇒ **Mars Lava tube Explorer** — The opportunity to pre-test such a probe in Earth orbit to improve our knowledge of lava flow terrain, makes this a logical priority. The results could be far less important for geology than for future Mars settlement scenario options. Ancient near-surface Martian limestone caves could also be identified.

⇒ **Mars topographic map** with accurate elevations: from which basin and watershed divides can be traced along with their overflow dam points. From this potential primitive and immature drainage patterns can be sketched. This will help avoid siting an outpost in a future flood plain.

⇒ **Geochemical orbital mapper** — A refly of the instruments aboard Lunar Prospector.

⇒ **Geochemical ground truth probes** — We lack even rudimentary mineralogical analysis of typical Martian soils. Without this, the path of industrial development on Mars remains totally fogbound.

⇒ **North & South Polar weather station net**

⇒ **Antarctic Mars Training Camp Base** in one of the cold but "Dry Valleys" like **Wrigh**t or **Taylor.** This should be a permanent establishment at which survival gear and methods developed for the Mars frontier can be tested, and prospective expedition members trained.

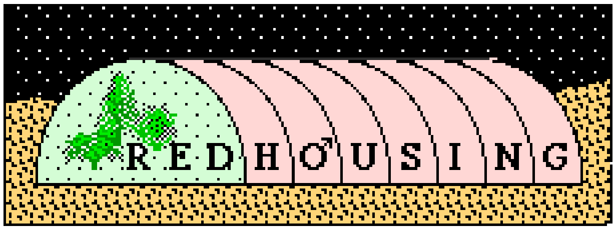
⇒ **"Redhouse"** Wild Flora Experimentation Projects. See the article with this name just below.

⇒ Adoption of the Zodiac-based **Mars Calendar** of Dr. Robert Zubrin as published in ***Ad Astra*** Nov/Dec, 93, pp. 25-7 "A Calendar for Mars", with the friendly modifications detailed in MMM #73, Mar '94, pp. 6-7 [pages 42-43 above]

Support is sought from: NSS, The Planetary Society, NASA, ESA, IAU (International Astronomical Union) Russian, Japanese Space agencies, SFWA (Science Fiction Writers of America)

[Note: We have since abandoned Zubrin's Mars Calendar and pushed our own "Mars Pulse" Calendar

http://www.lunar-reclamation.org/mars/marspulse_cal.html



Breeding "Mars Hardy" Plants in Compressed Mars Air

By Peter Kokh

In the previous "Mars Theme" issue, MMM # 83 MAR '95, on pp. 7-8 "Searching for OLD LIFE on Mars" (P. Kokh), we broke the topic down into two separate questions:

Question 1: What kinds of life forms may have had time to evolve on Mars before irreversible climactic decay, and could any fossil traces still endure?

Question 2: Could some anemic relic of a once far richer Martian Biosphere still subsist in "oases" here and there?

We concluded with a discussion of the implications for Martian settlement dreams, pointing out that the Romanticists who hope against hope that we will find some primitive (at least!) life forms still extant life on Mars, had better hope that they are wrong. It is incomprehensibly naive to think that should we find life on Mars *of any sort*, that the political / rabbleocracy powers-that-be would allow humans (us!) to settle there. The Fourth Planet would forthwith be declared a quarantined biological preserve for the rest of time. "Humans and all Earth Life keep out!" We could hardly disagree more with the sentiments expressed by editor Jeff Liss in the recent issue of **Inside NSS**. He had called "disappointing" the recent finding that the Viking "No-Life-On-Mars" experiment results were not flawed after all.

If all we find are fossil relics and perhaps a few incomplete strands of DNA (we should rejoice at finding that much!) Jurassic Park type reconstructions of native life form populations are most unlikely.

If an ecosystem does survive, we could not hope to see *any significant further evolution* (beyond anecdotal differentational radiation of surviving species into new niches in a restored or rejuvenated more benign climate) within the lifetime of humanity, even if it be a million years - and *not even if* we succeeded in restoring, permanently, the former more life-accommodating climate with a stabilized all-Martian biosphere and biota. Romantic ideas to the contrary should not be entertained. We would be left with only pre-metazoan life, one-celled plants and animals - *nothing we could see with the naked eye!* So rather rejoice that Mars is empty of life!

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 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 rejuvenaissance of the planet. Rather than "terraforming" Mars by making it a copy of Earth, rejuvenaissance 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 alias 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.

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

What we have to start with is, species after species, a long ways 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.

Animals, however, need an oxygen-rich atmosphere, which we don't have, have never had, on Mars. Plants, in contrast, 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 to say, that plants and crops can be grown on Mars in greenhouses pressurized with warmed Martian atmosphere, simply compressed tenfold - nothing else added, besides water, of course. That we could gradually lower temperature and pressure 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 is the general idea.

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 to evolve 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 to much for them. Witness the tree line!

Some antarctic organisms in the animal kingdom, come equipped with an intracellular antifreeze - glycol. But plant cells have protoplasm as well. If the gene responsible for the ability to produce glycol can 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. On Mars 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 among the most challenging niches for desert life.

And then there is the untempered **ultraviolet** of the more distant, cooler, Martian "Sun". Mars tenuous atmosphere without free oxygen (O2) or ozone (O3) 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.

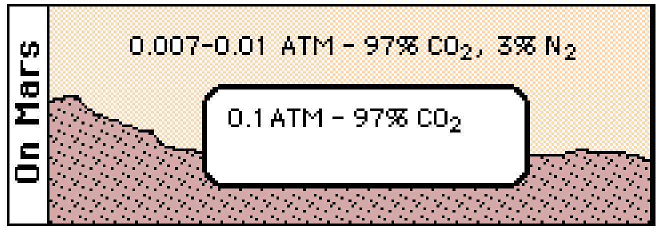
We must add one more characteristic. On Earth many plants are pollinated by insects and birds. Bioengineering animals to breath a carbon dioxide atmosphere seems science-fantastic, not merely science-fictional. So we may want to end up with plants that are **wind-pollinated** or use some other assist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

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.

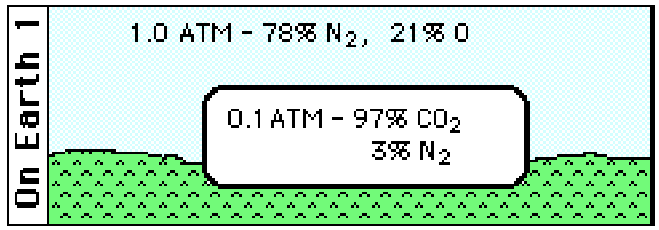
What plant forms will be most receptive to such diverse genetic additions? Your guess is as good as mine. It is not impossible that the best Mars-hardy hybrids will have as ancestors plants that boast none of the assets mentioned, but will have proven receptive to all of them.

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.

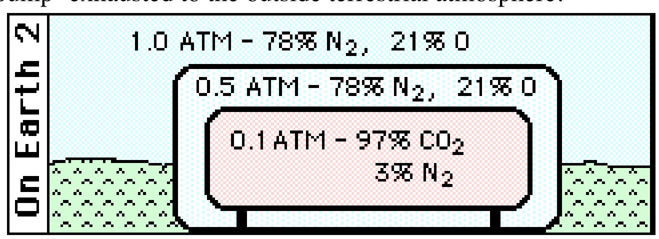
On Mars, as we pointed out, all we will need is a shelter that holds compressed, warmed Martian air.



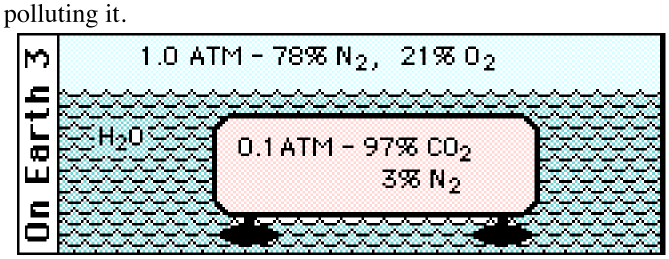
On Earth it will be a little trickier. Unbuffered, the facility would be subject to inexorable leaks from the higher pressure, vastly more oxygen-sweet air of the host planet:



One way we can buffer the facility and prevent hasty degradation of the special atmosphere within, is to use 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. This would also tend to prevent atmospheric contamination. A wet porch could not be used for entry, however, as 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 Mars redhouses Meanwhile, 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 compromise - 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 smoothed. 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 and the Plan for Mars

As progress allows us to preview the eventual results, we will know better 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 eventually free standing and/or flowing open water. The Mars Orbital Laser Altimeter aboard the Mars Global Surveyor (November '96 launch, September '97 arrival) will give us a good idea of where these oases-to-be are located. We will then even be able to speculate about setting aside right-of-ways for future parkways.

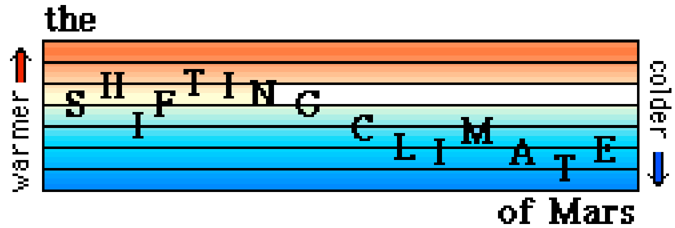
Redhousing in the Grand Design of Things

To return to the point we made at the outset, if Mars is devoid of life, that makes is a virgin world, not a barren one. The cosmic vocation of humanity, unsuspected by all the world's pretentious scriptural traditions, 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 (meant as the name of Earth-Life in aggregate, not as some mythic meta-individual).

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.

Make a Mars "Redhouse"
with controls, entry safeguards etc.,
as a chapter project
or school science project
for public display, including at ISDCs

Be a Doer, not a Watcher.
The watcher is likely to be disappointed.
The doer has the comfort of knowing
that he has tried, and perhaps laid foundations,
for others who follow, and may reach the goal.



And the challenges for those who need data points for their terraforming schemes

By Peter Kokh

Those brave optimists who essay to put together various schemes to bring about major climactic and environmental changes on Mars in order to render the planet much more appealing a destination for would be Earth-forsaking homesteaders, can, at present, do little more than B.O.E. ("back of envelope") calculations of the material and energy inputs and relocations needed to bring about such changes.

Whether the goal is "terraforming" (making the planet another "Earth") or "Lowellification" (making the planet at least as friendly as we thought it was fifty years ago), or "rejuvenaissance" ("restoring" Mars to its wettest and warmest former state of about three billion years ago), the equations are hard to work without good data about the present.

In point of fact, despite all the revelations of the Mariner and Viking missions, we know much less about the Mars of today, than most writers will admit.

(1) We don't know within two or even three orders of magnitude how much water remains on Mars, locked up in the polar caps, in subterranean aquifers and lakes, or chemically bound up in hydrates, or frozen in the interstices of soil particles as permafrost. Nor is such vital information the target of instruments aboard presently budgeted missions to Mars.

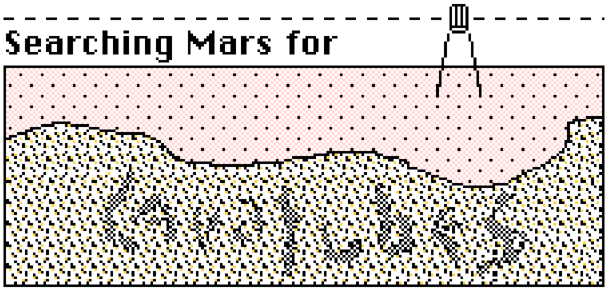
(2) We don't know how much carbon dioxide is locked up in clathrate frosts at the poles, nor how much may be chemically bound up in sedimentary carbonate rocks or limestone layers.

(3) We have only a very crude idea of the relative altitudes of Martian surface features, and thus only a very imperfect idea of potential drainage basins and watersheds. Fortunately, this ignorance is being addressed by the **Mars Global Surveyor** ready for launch later this year.

(4) Hubble has shown that what we thought we "knew" of Martian temperature ranges, was pegged to a transitory condition.

Apparently, mean temperatures on Mars have dropped an astonishing 20° in the two decades since Vikings I and 2 established weather stations on the planet. By comparison, a mere 2° rise in terrestrial temperatures worldwide, would cause environmentalists and meteorologists and climatologists to reach for the panic button.

At the moment,we have no idea how long-lasting this cooling will be, nor even if the downward swing has bottomed out, nor on what time frame such meta-seasonal changes take place. Given that, brainstorming pathways to a friendly future are interesting fantasies and no more. As they say, "garbage in, garbage out." Yet carefully designed future missions could tackle each of these points of our ignorance quite well.



Mars' vast shield volcanoes & lava sheets are prime territory for lurking lavatubes & prime real estate for the New Martians

By Peter Kokh

Whatever geological and scenic attractions may beckon siren-like to the first manned Mars expeditions, the "california" of future waves of Martian homesteaders is more likely to be the expectedly lavatube riddled shield volcano flanks of Olympus, Arsia, Pavonis, Ascraeus, and Elysium - and likely similarly endowed vast lava sheets of the attendant Tharsis uplift region.

The pre-excavated radiation shelter and the thermally buffered retreat of the tubes will make any settlement establishment much easier, giving it a considerable head start, as well as an enduring advantage. Mineralogical assets will also count, of course. And happily, the Tharsis region impinges on the head of the great Valles Marineris canyonland complex where many strata of rock will lay revealed for prospecting ease. **Pavonis Mons**, a great shield volcano already cited as possibly the most strategic mountain massif in the entire Solar System, its western flank the ideal site for a launch track complex, neighbors this canyonland head region on its eastern flank. [Cf. MMM # 18 SEP '87, pp. 6-7 - MMM Classics #2]

But all this is little more than reasoned speculation. We do know what kind of terrain sports lavatubes on Earth and we do see analogous terrain on Mars. But that's it. On the Moon we have the added advantage of seeing actual examples of partially and wholly collapsed lavatubes (e.g. Hyginus and Hadley Rilles, respectively). Surveying such features on the ground will take generations. If we can search for them with orbiting instruments, our pre-settlement "treasure" maps of Mars will be enormously more helpful and propitious.

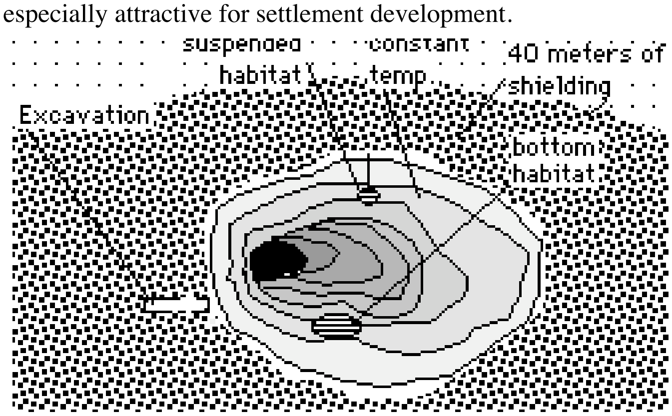
While many, if not most tubes may lie within lava sheet layers that have been subsequently buried by later flows and thus be well below the surface, those in the uppermost flows should lie near enough to the surface to be detectable by appropriately tuned radar.

Cf. MMM # 44 APR '91, p. 6, in which we report on the suggestion of Tom Billings of Oregon Moonbase (and published in Oregon L5's **Starseed**) that since airborne radar had been used successfully to find lavatubes on the Big Island of Hawaii [i.e. the Mauna Loa / Mauna Kea shield volcano complex], given the dryness of the lunar [and Martian?] surface, it should be possible to map near surface tubes with orbiting radar. To penetrate deeply enough we would need a wavelength of 5-20 meters, meaning an antenna 20-80 meters across.

Given our experience with the quixotic results of some of the Viking lander experiments, it only makes sense to fly such instruments first in low Earth orbit. We can then compare the findings with known "ground truth" and check the verisimilitude of the readings and better correct the calibration. Finding unsuspected tubes in various regions on Earth may be reward enough to merit such a precursor mission.

This being done, a second such orbiter mission could do its tricks in orbit above the Moon, adding enormously to the practical knowledge necessary for intelligent planning of lunar development scenarios. The third tubefinder mission would head for Mars polar orbit. Lessons learned at Earth and at the Moon would allow mission planners to fly the leanest and lightest and least expensive probe to Mars capable of doing the job usefully well.

Would permafrost deposits interfere with the readings and conclusions. Not likely, as the radar wavelengths for the former are LONGER - SHORTER by a factor of X. However the radar instrumentation needed for the two global searches would seem to make made-in-heaven bus mates — a "tundra and tube" mapper. If we did find permafrost and tubes in the same region,. and we may not, that would mark the location as especially attractive for settlement development.



LAVATUBES AND THEIR USES: On Earth, these features are typically a few tens of meters wide and high and hundreds to a few thousands of meters long. On the much less gravid Moon, and with the scale of Hadley Rille as evidence, we expect to find lavatubes hundreds of meters wide, and many tens of kilometers long. On Mars, with its in between 3/8ths normal gravity, we might expect such features to be in between in size, say 50- 100 meters wide and a few kilometers long. On both the Moon and Mars, "tubing" will be a major outdoor hobby, akin to limestone cave spelunking on Earth.

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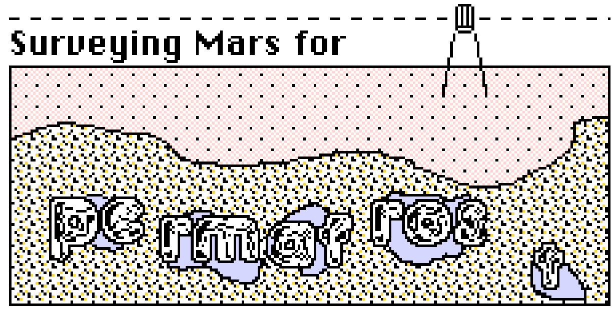
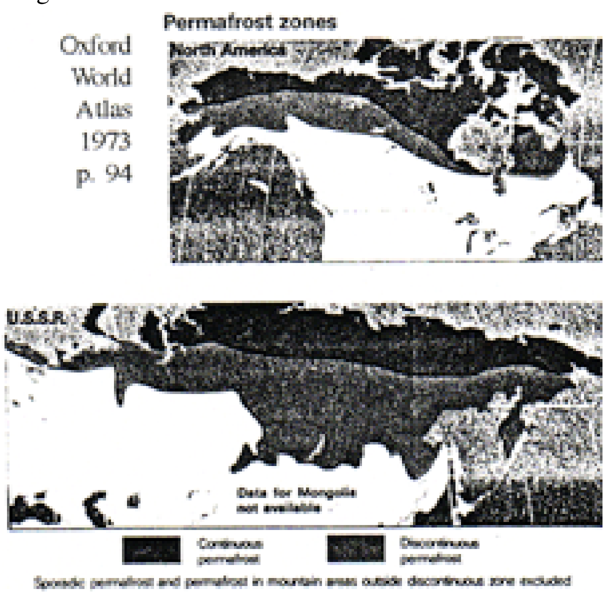


By Peter Kokh

PER•ma•frost: [from perma(nent) + frost] perennially frozen subsoil. Also called *pergelisol*.

Where do we find permafrost (on Earth)?

We find permafrost mostly in circum arctic lands of Alaska, Canada (Northwest Territories, northern Quebec, northern Labrador), Greenland, Iceland, Scandinavia (Norway, especially), and Russia-Siberia. Permafrost is the soil condition that manifests itself in "**tundra**" type no-root or shallow-root vegetation.



[*loc. cit*.: Permafrost can be differentiated into 3 main zones: (a) continuous permafrost, where very little land is unfrozen and where permafrost may reach depths over 600 meters or 2,000 feet; (b) discontinuous permafrost, where patches of unfrozen ground occur; and (c) sporadic perma-frost, where patches of permafrost occur in a generally unfrozen area. Overlying the permafrost is an 'active' layer of rock or soil which thaws in summer and freezes in winter.]

How does permafrost form?

Permafrost forms in ground water areas through gradual transition to ever more severe winters and ever shorter and cooler summers. The deeper the ground water penetrates, and the greater the water content per volume of soil, the thicker and richer the permafrost layer.

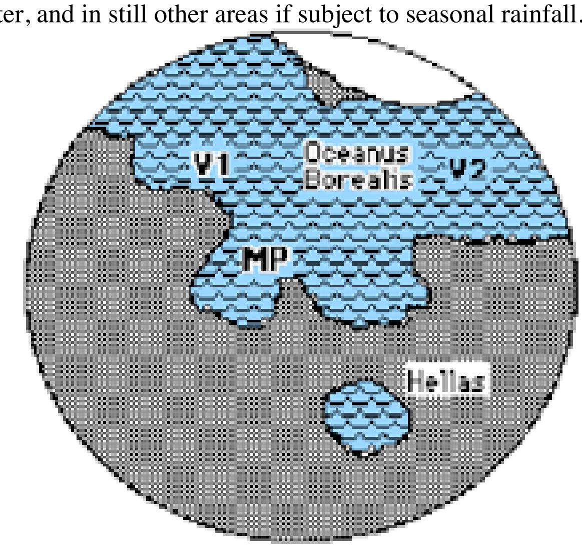
Why there may be extensive permafrost deposits on Mars?

There is abundant evidence from high resolution Viking photos of landforms for which the only plausible explanation is that they were formed by water: tear drop shaped islands in the middle of large valleys, relic beaches and ancient shorelines, wave-sculpted dry lake and sea shore bottoms, deltas and estuaries, flood-carved channels. From such evidence, it has become clear that Mars even sported a respectable northern hemisphere ocean that once covered more than a third of the planet to respectable depths. Not all of this water could have evaporated or sublimated into space. Archaic water-saturated lake and sea bottoms should have retained their water content as the climate got colder and the ground froze to deeper and deeper levels.

Where on Mars is permafrost most likely to be found?

The likeliest areas of significant permafrost deposits are the ancient northern ocean bottomlands, deep major impact basin bottoms like Hellas and Argyre, and canyon bottoms (especially the outflow areas like the Ares Valley landing site for the **Mars Pathfinder** lander. Unfortunately, this lander is not providentially equipped to test for permafrost underfoot. It is typical that the kind of knowledge most needed to assess settlement feasibilities is low on the priority list of planetary scientists interested primarily in scratching the itches of their own narrow scientific curiosities. Both Vikings likewise landed in areas in which we might expect to find substantial permafrost deposits, a condition that went untested.)

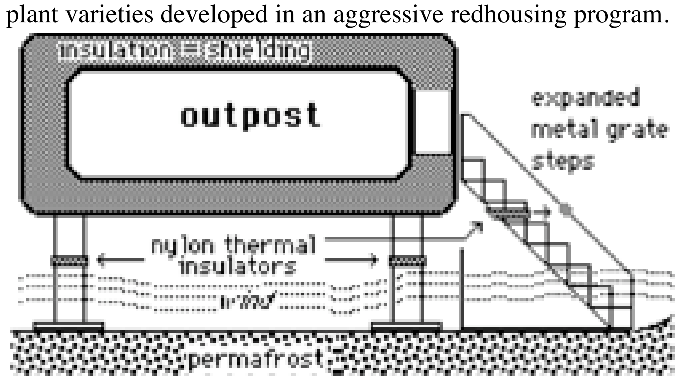
Permafrost could have formed in adjacent areas not covered by standing water through the lateral spread of ground water, and in still other areas if subject to seasonal rainfall.



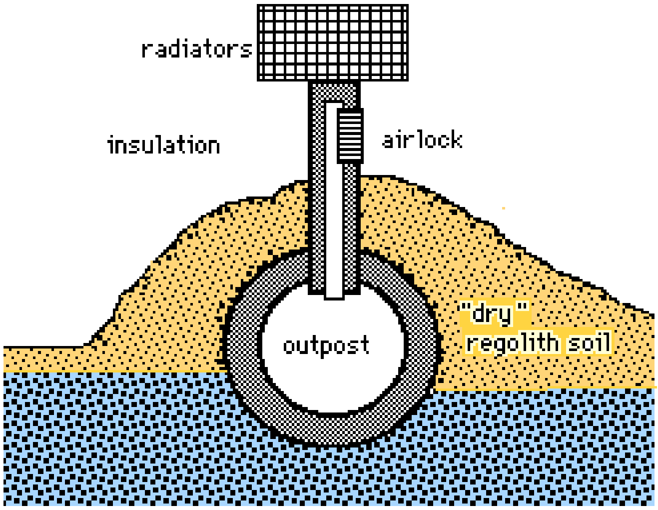
What, if any, would be the significance of permafrost on Mars for future settlement / development?

On Earth, **(a)** permafrost renders the land agriculturally unproductive, although tundra lichens and other vegetation is sufficient to maintain a large wildlife population of caribou, rabbits, and other hardy arctic fauna. **(b)** Buildings must be set on bedrock or thermally isolated from the ground, commonly by use of stilts made of materials with low heat conductivity, along with effective use of insulation to prevent heat radiating from the bottom of the building to the frozen soil below. The stilts should raise the underside of the building high enough above the ground to allow free air and wind circulation. **(c)** Road building creates special problems: special measures had to be taken during the construction of the Alaska Pipeline.

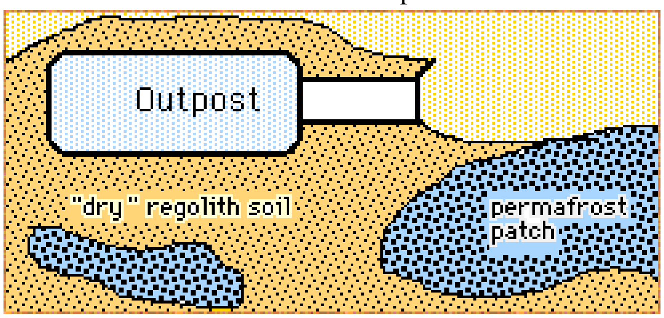
On Mars, seasonal thaws may not be a problem at first, but may become more extensive as activities, planned and unplanned, lead to a significant warming of the climate. (a) For this reason, outposts in permafrost areas will be especially challenging to build and maintain. Settlement may be limited to areas of patchy permafrost, with construction held to frigid *but not ice-saturated* soil and rock areas. (b) Only those areas where the 'topsoil' is 'active', i.e. thawing seasonally, will be colonizable by bioengineered Mars-hardy plant varieties developed in an aggressive redhousing program.



Above: Mars outpost on stilts- insulated



Above: Mars subsurface outpost - insulated



Above: Mars subsurface outpost in "patchy" area

How can we tap permafrost water assets?

(1) We *could* strip mine the permafrost layers and then run them through melting ovens on conveyors, redepositing the dried soil back in place, all in one operation. This could be more mechanically difficult than it sounds, with lots of equipment breakdowns, given the hardness of the soil/ice aggregate.

(2) We could heat the deposits in situ (in place) and then pumping out the freed and liquefied water if excess waste heat at a high enough temperature is available. This requires drilling holes for heat conducting rods or superheated steam pipes. Such waste heat would be available if the outpost had a small nuclear plant both for heat, power and for extraction of various atmospheric gasses.

(3) We can cover the frozen ground with an "infrared-black" plastic tarp and apply concentrated solar heating.

Which ever method we use to extract the ice-melt, it may be necessary, if the water proves to be saline, to distill the melt to purify it of salts (and possibly heavy metals). A few "ground truth" cores taken by rover drilling probes would soon establish just how fresh or how brackish the permafrost ice is, and whether it varies in quality from place to place.

Excess water produced by an outpost's local permafrost tap may then be trucked, or airlifted, or eventually pipelined to other less advantaged settlements and outposts. Thus, water could well be the first real intra-Mars trade commodity. (A futures market, anyone?)

What alternative sources of water are there?

Other most options for providing water needed for drinking and hygiene, agriculture and life support, processing and manufacturing do exist:

(1) Nuclear powered atmospheric hydro-extraction plants are certainly feasible. In 10,000 tons of Mars air, there are 3 tons of water vapor, i.e. 0.03%, plus 7 tons of oxygen and 270 tons of nitrogen, both of which would also be extracted as byproducts. Each outpost or settlement is likely to have such a plant anyway, to produce carbon monoxide and methane fuels as well as fresh oxygen and nitrogen. The question is, will such a plant produce enough water in the process to meet demands, or will this "air-water" need to be supplemented?

(2) A much bolder and higher cost option would be to mine ice from the edge of the north polar cap (the southern cap may be mostly carbon dioxide frost). Melted, this glacial melt could then be trucked (requiring roads or ground effect vehicles) or (especially later as population on Mars and demand grows) a network of aqueducts would follow the paths imagined by Schiaparelli and Lowell from the north polar cap southwards. (cf. MMM #62 FEB '93, pp. 6-7 "CANALS on Mars" [republished in MMM Classics #7] and MMM #73 MAR '94, p. 5 "Canal Names" - Read in MMM Classics #8) One or both of these options can serve "ice-dry" areas of Mars.

Putting together a Mars Permafrost Map - Now

Because extensive permafrost zones are found here on Earth (some continuous, some discontinuous, some patchy), we have an ideal opportunity to fly the needed radar instrument package in polar Earth orbit to both test how well it can detect permafrost and to properly calibrate the instruments by checking their readings with actual data on the ground, so we will have greater confidence in interpreting the readings we get in flying an identical instrument package around Mars. We need to determine how well depth of the layer below the surface, ice content percentage, and thickness of the deposits are indicated in the readings, and whether differences in salinity or other factors affect the data points we get.

If flown alone (not with lavatube radar) as a US - Russian mission, **Bering** (Russian-born explorer of Alaska, Vitus Bering) might be a good name for the probe. **Mars Permafrost Mapper** would be an alternate choice.

A Space Frontier **Tech Demo** Program

IDEAS for Lo-budget, 2 yr.-feasible demonstrations of technology items that will be needed or useful on the **Martian Frontier.**

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[* The following suggestions by no means exhaust the possibilities and readers are encouraged to think of, pre- brainstorm, and report to MMM of other neat doable projects that will help bring home to all of us, veteran space enthusiasts and general public alike, the concrete doability of space pioneering on the Moon, Mars and elsewhere in the Inner Solar System.]

The "Mars Engine"

The goal is to produce a motor vehicle engine for use on Mars that will burn fuel and oxidizer derived from Mars' atmosphere and whose combustion products will return to the atmospheric gasses from which they were derived. Two fuel combinations are possible: "**Carmonox**" engines will burn carbon monoxide (2 CO +O_2); "**Methanox**" or "**Oochie™**" engines will burn methane (O_2 + CH_4). Methane is the more powerful fuel and will be the fuel of choice if reasonably salt-free water can easily be produced from permafrost taps.

The GOAL of this tech demo is not a vehicle chassis suitable for Martian terrain, but an engine that can be used in any such vehicle: car, truck, coach, caterpillar, etc.

START: There are *now* any number of experimental methane burning vehicles already on the road. REPLACE the carburetor with bottled oxygen and combine with the methane in an INTERNAL COMBUSTION cycle, not a rocket motor.

AND DEBUG. DEMO at ISDC '98 Milwaukee.

A Mars Airplane

The density of Martian air at average surface levels is equivalent to the atmospheric pressure on Earth at 125,000 ft., an altitude that can be reached by a baloon-mounted platform. DESIGN, BUILD, and FLY an unpiloted airplane to and from such a platform - at or during ISDC '98 Milwaukee.

Paul Swift of the Ontario Space Society (ISDC '94 Toronto) has expressed an interest in taking up this challenge.

Mars Meteorburst Experiment

Meteorburst communications in which messages bounce off the electronic debris trails of incoming meteors high in the atmosphere have been used successfully for over-the-horizon communications by long distance trucking companies. The devices never having to wait more than a second or two before finding a suitable placed meteorburst.

Because these events occur high up, this system also should work well on Mars, as a reliable backup to a more expensive to deploy and maintain satellite communications system. DESIGN, BUILD, and FLY such a system, again aboard a balloon-hung platform at an altitude of 125,000 feet.

Igloo shielding sebatier reactor

Can shielding be manufactured by a sebatier reactor from atmospheric components on Mars? If so, a small nuclear thermal power plant could enshield a telerobotically landed Mars habitat module or complex without disturbing the boulder strewn and possibly permafrost hardened soil all around the campsite to be.

One possibility, in theory, is DiNitrogen Pentoxide, N205, which is a white powder throughout the whole range of Martian ambient temperatures. It is dangerously chemically unstable, however. A much safer product would be simple carbon (graphite) dust, powder, or crystals.

DESIGN, BUILD, and DEBUG a sebatier reactor device to start with a Mars-like atmospheric mix and end up with such an inert thermal shielding powder. Make note of any potentially useful atmospheric byproducts produced in the process. DEMO at ISDC '98 Milwaukee.

Mars Hovercraft or Skimmer

Traversing Mars boulder-cluttered strewn-fields will be slow going and impede easy, frequent, and timely travel between outpost sites on Mars by wheeled vehicles or legged walkers. A hovercraft which could skim over such routine obstacles at speed would open up the planet like nothing else could. Mars' low atmospheric density, however, makes a traditionally designed hovercraft infeasible. If the weight of such a vehicle, with cargo and fuel, could be partially (say 90%?) compensated by hydrogen aerodynamically styled buoyancy bags, perhaps such vehicles could work. Hydrogen is safe to handle on Mars where there is no free oxygen to speak of.

DESIGN, BUILD, TEST, and DEBUG a scale model Mars Skimmer. DEMO at ISDC '98 Milwaukee.

A Mars "Redhouse"

Unlike a "greenhouse" which maintains terrestrial plants under Earth-normal ideal growing conditions in less than ideal climates, a "redhouse" would be pressurized with relatively pure Carbon Dioxide, CO_2. BEGIN with the hardiest plants known on Earth, lichens and other tundra plants; plants that thrive in the high altiplano of the Andes, and at the tree line of other high altitude areas; plants that thrive in desert conditions; plants which survive intense cold.

The eventual goal of "redhousing" will be to breed ever hardier and hardier hybrids which someday may take hold and survive outdoors on a Mars where human intervention has succeeded in meeting them halfway by raising the carbon dioxide atmospheric pressure and ambient temperatures.

For ISDC '98 Milwaukee, the goal is simply to DEMO a redhouse chamber with controls capable of varying the pressure and temperature.

HOW TO PROCEED:

The game plan:

- Gather a team with the right mix of expertise,
- Brainstorm a design
- Price the materials and tools that you will need
- Make a presentation to potential corporate sponsors

Mail Box

Is Mars more impact prone than Moon?

It would seem to me, that settlers on Mars could be more exposed to meteorite bombardment than pioneers on the Moon. Mars weighs in some 5 times heavier than the Moon, giving it more gravity [3/8ths vs. 1/6th Earth-standard] and hence a bigger/wider/ deeper gravity well. This means it will "catch" more asteroidal and cometary debris, *and* impose on it higher velocities of acceleration prior to impact.

Mars tenuous atmosphere will burn up the micrometeorite stuff, so that Mars' surface is not subject to the steady 'rain' that the lunar surface undergoes. It would follow that the dust on Mars is from weathering, rather than impact "gardening". But the larger stuff will not be stopped and much will get through that incinerates in Earth's much thicker atmosphere.

Further, Mars is much closer to the main asteroid belt and probably is exposed to a thicker concentration of debris than the Earth-Moon system.

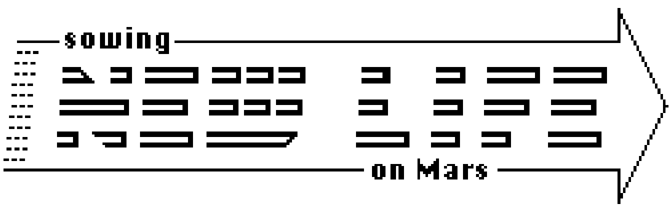
We should not be misled by visual and photographic comparisons of the Martian and Lunar surfaces at various resolutions. Unlike the Moon, Mars experiences real weather (wind, and scattered freeze-thaw cycles) and formerly underwent major episodes of volcanic activity. This gives its surface a deceptively younger, less impact-scarred look.

Not to scare anyone away. The heavy lunar bombardment we see happened mostly more than 3 eons [3 billion years] ago, and danger to pioneers will be less than us terrestrials face in volcanic eruptions, earthquakes, hurricanes, tornadoes, lightning, avalanches, landslides and other catastrophes from Earth's active geology and weather systems. The same should be true on Mars.

Thomas Heidel

Milwaukee, Wisconsin

EDITOR: Thanks Tom. You have summed up the situation accurately.



A book review of the second in the epic trilogy of Martian Exploration and Settlement

GREEN MARS

Kim Stanley Robinson

Bantam Books, New York 1994

ISBN 0-553-09640-0 (HC)

Reviewed by David Dunlop, LUNAX Corp.

I enjoyed **Red Mars** immensely. **Green Mars** was a continuation of the pleasure. Many of the same characters appear in the narrative and the Marsscape and supporting technology picture is essentially the same. **Green Mars** is a continuation of the saga of Mars-a-forming and paints a picture more focused on the psychological struggles and political and sociological tensions of the development of a three world economy.

Kim Stanley Robinson favors the dark side of the human and political character in developing his scenario of the Martian future. His portrait of unrelenting corporate greed and manipulation of the political and financial investments in the development of Mars provide the backdrop for the emerging Martian identity and struggle for a self sufficient independence.

In **Red Mars** a gigantic orbiting tether is built from asteroidal resources to provide an elevator to orbit from the Martian Surface. This is destroyed by Martian settlers focused on independence. In **Green Mars** they build another one.

One missing component of this Saga is sufficient background on the context of Earth politics which are assumed to be driven by disintegrating economic and environmental circumstances. If there is any potential weakness in Robinson's formulation it may be that an Earth not in pursuit of its own advantage could not be rationally foreseen to continue to make enormous investments in Mars. From historical grounds one cannot question that Robinson's picture of human motivations in initiating a colony or attempting to continue to control the colony and protect the investment in the colony is unrealistic. However the sustaining economic and political commitments that settling and terraforming Mars will require will also require a political and economic structure than provides a continuing flow of benefits to those on Earth. It is difficult to imagine a sustaining commitment to Mars that would not be more benign in terms of the polarization that massive destruction and war create. It is also clear that great economic growth in the aftermath of war occurs as a result of technology deve-lopments made for the waging of war.

The Moon as a staging area for Martian settlement and the base of an Earth/Moon economy are not clearly visible as structural precedents of the Martian development. One could just as well have argued for a saga that followed more of an antarctic base buildup than the explosive expansion pictured in Red Mars and **Green Mars** would be more likely. The nano-technologist would of course dismiss all of this as a quaint picture of pre-nanotechnology scenarios.

The more benign scenarios I have suggested would of course deprive Mr. Robinson of the dramatic backdrops of violence. Where (in the solar system) would the poor novelist be without sex and violence? Out of the popular market I'm afraid.

There is little in **Green Mars** to dissuade me from looking forward to the next in the Trilogy **Blue Mars**. After all if you are stuck in the house during a spell of 30 below weather would you rather spend an afternoon in the tub reading about the dramatic adventures of the nanobots? ***DD***

Serious Non-Fiction on the Topic

Schemes for long term *terraforming* of Mars abound. But the following book outlines one proposal for a quicker fix.

The Greening of Mars

Michael Allaby & James Lovelock, 1984.

The authors propose that the world stockpile of CFCs be payload for the world's stockpile of ICBMs, all retargeted for Mars, where the CFCs would contribute a maximum "green-house effect", putting the temperature of Mars over the threshold where the carbon dioxide trapped in the polar caps would permanently melt, thickening the atmosphere to the point that liquid water would be stable on the surface and the "greening" of Mars with hardy genetically reengineered plants from Earth could begin.

They see no place for animals in this scheme. The thickened atmosphere would be fine for plants but unbreathable to humans, so the latter would continue to live in pressurized habitats or underground cities [*with their pets, and urban wildlife, the author's indifference to animals not withstanding!*]

James Lovelock had previously co-authored the more widely read book "**The Gaia Hypothesis**" with noted biologist Lynn Margulis. **<MMM>**

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