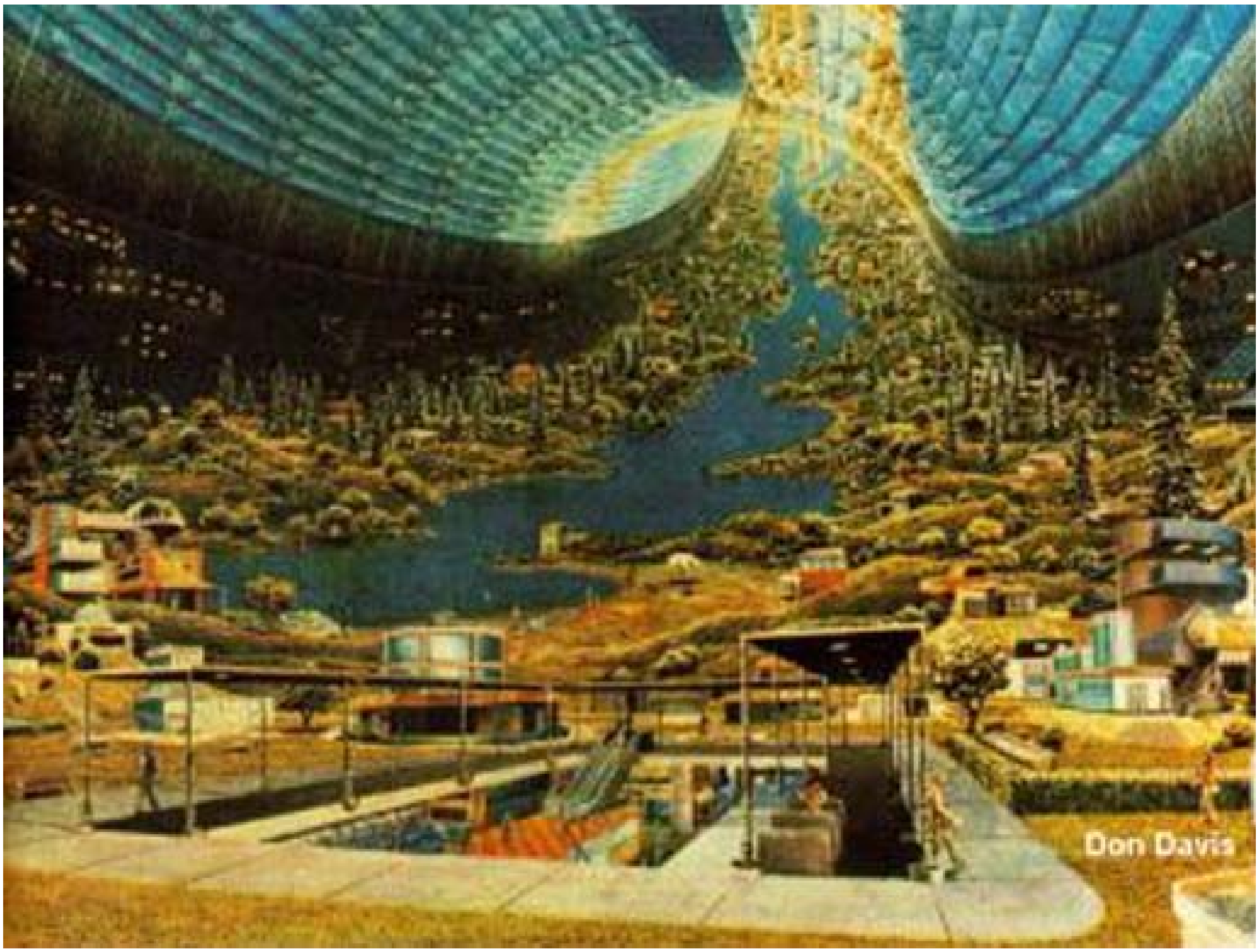
EXPANDING THE HUMAN ECONOMY THROUGH OFF-PLANET RESOURCES

MOON MINERS' MANIFESTO

MMM Classics	Year 2: MMM #s 2-20
The First Ten Years	December 1987 November 1988



ABOVE: *Inside the Stanford Torus* - MMM #s 11-13 take a fresh new and critical look at the concept and now classical designs for Space Colonies or Settlements à la Dr. Gerard O'Neill - in a six part series. But there is much more in this collection of articles from MMM's second year. Enjoy! For updated information about Moon Miners' Manifesto, simply go to: www.MoonMinersManifesto.org

MMM Classic pdf files are online at: www.lunar-reclamation.org/mmm/classics/

To read these files, you will need Adobe Acrobat Reader, a free download from www.adobe.com)

Address all comments to the Editor, Peter Kokh, at kokhmmm@aol.com. Selected letters may be published in future tomes.

SPACE OASES & LUNAR CULTURE

MOON MINERS' MANIFESTO. has been cast, even by well-meaning admirers, as a "special interest" newsletter. As editor, I have to take responsibility for this widespread mis-appraisal. I had stated that we wanted to explore the heights to which a self-sufficient lunar civilization could rise, given the con-strain that it must seek to develop as far as possible relying solely on lunar ores that are poor in hydrogen, carbon, and nitrogen. The *MANIFESTO* has gotten good marks for this effort. But for many whose dream is life on O'Neillian space colonies, these discussions have perhaps seemed irrelevant.

This shows our failure to realize that what may be perfectly obvious to us, doesn't necessarily suggest itself to others: namely, that *in the early decades,* the availability of volatile-rich ores from asteroids and other sources cheaper to access than upports from Earth, will be at best sporadic. As a result, pioneers in free space oases will find them-selves in much the same straights as hardy lunar settlers. Unless they are fantastically prosperous [pluck your brains out of free fall!) and can afford heavy dependence on Earth-sourced materials, they too must build their cultures largely on the possibilities inherent in volatile-poor lunar ores. Lunar cultures will be the rule.

Thus, *in the early decades,* space colo-nists too will be forced to give up a way of life based on the causal use of paper, wood, plastics and the whole host of addictive synth-etics based on hydrogen, carbon, and nitrogen so very abundant on Earth. This will color their whole way of life with its implications for building products, household furnishings and other domestic wares, clothing, information media, sporting goods, toys, arts and crafts etc. If you are truly interested in pioneering free space, you will find enlightening ideas on what such *frontier life* will be like in the pages of *MOON MINERS' MANIFESTO.*

We belated invite you aboard our *Mainline Express* to a thousand space futures. To catch up, as we have already left the depot, check out the articles and essays from the earlier issues. - Peter Kokh 11/87

The original article is online at:
www.asi.org/6/9/3/2/011/space-oases-intro.html

This and the following two issues of MMM are dedicated to those for whom lunar settlement is nly a necessary means to another horizon on which their true interest lies:

Oases in Free Space or Space Settlements/Colonies

This most revolutionary of human dreams for life beyond Earth *needs a fresh approach.*

SPACE SETTLEMENT QUIZ

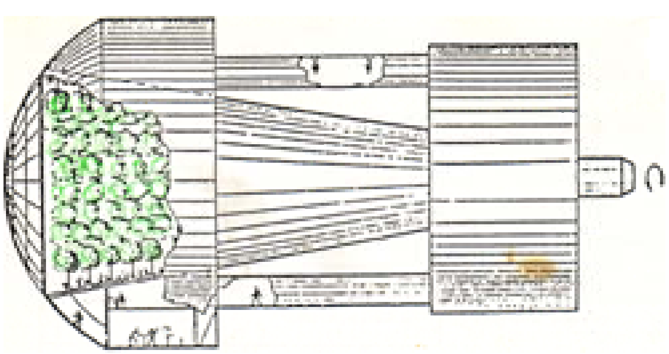
QUESTIONS

1. The trailing lunar co-orbital field "Trojan" position usually referred to as L5 is no longer seen as the best space colony loca-tion. But if one were located there, how long would it take to orbit the Earth?
2. Of what use is the preceding co-orbital "Trojan" called L4?
3. How much easier is it to reach the 2:1 resonant orbit than L5 from L2?
4. In the proposed resonant orbit, how close will the colony come to Earth at perigee, and how close would it come to the Moon at every other apogee?
5. What environmental problems does a space colony face that will be less troublesome for a lunar settlement?
6. Name some interesting groups of characters that you are less likely to meet on a space colony than in a lunar settlement.
7. You live on a space colony and your doctor says you need more exercise and advises you to start jogging, but cautions that you should run only westward at first. Why?
8. Which traditional performing art will be somewhat more difficult to master on a space colony than on Earth?
9. What will homes inside a space colony be built of?
10. What sort of trees and other plants would you expect in a space colony park?

ANSWERS

1. Same as on the Moon, of course: 27.5 days by the stars, 29.5 days by the Sun.
2. Same as L5. Since taken together these two positions offer an unchanging vantage point over 5/6ths of the Moon's surface (all but "deep farside") they will be important for communications, surface navigation etc. especially as there is no moon-synchronous orbit, only these two moon-synchronous positions. But quite apart from this, again taken together, L4 & L5 form a very conve-nient baseline about 400,000 miles (650,000 km) long for astronomy, providing the opportunity for unprecedented interferome-tric resolution, for radio astronomy,
3. A Delta V of only about 30 ft/sec (vs. 1400 ft/sec to L5) is needed.
4. About 100,000 miles from Earth and on the order of 40,000 from the Moon.
5. Removal of waste heat (the lunar subsoil at -50°F and the two week long nights both help) and the dust and debris from manufac-turing and processing (one sixth gravity will scavenge these out of the near-surface vacuum whereas they will tend to form a Sargasso Sea about the space colony, sharing its orbital momentum and following it about, dissipating possibly at a slower rate than that at which it builds up.

6. One could mention amateur astronomers, prospectors, over the road drivers, mountain climbers, spelunkers, etc.
7. Running westward, against the direction of spin, you will be subject to lessened centrifugal force (artificial gravity) and thus “weigh” less, and this will be easier on your lazy heart. Seasoned runners will head eastward, in the direction of spin.
8. Dancing, especially Ballet and Modern Dance, because of especially strong coriolis forces within rotating environments with short radii like space oases. Rocking in place will be easier.
9. Lunar concrete, ceramic blocks, and glass-glass-composites will be cheapest. Pure metals and alloys will be reserved for accent or sub-systems. Wood? Never! Withdrawals from the biosphere Biomass will be discouraged as they will cost the replacement value of the precious volatile elements involved.
10. The exact species will depend on the colony’s climate, but since space will be at a sever premium, one would expect only utilitarian plants: fruit trees, berry bushes, herbs, and plants that are a source of useful cosmetics, pharmaceuticals and dyes. The challenge will be to arrange these in a way that is delightful as well as practical.

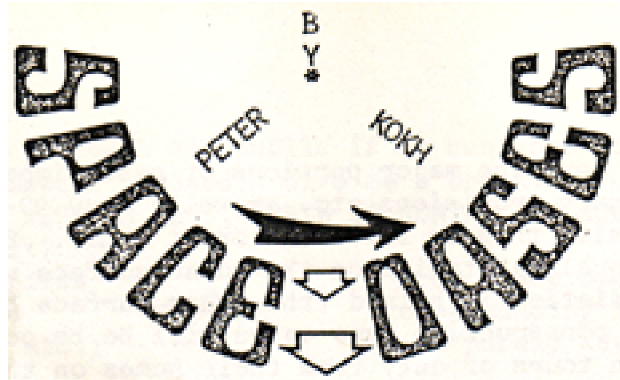


Konstantin Tsiolkovsky’s early 1900s concept for a space station with artificial Gravity.

This concep featured the main requirements of a genuine oasis in space:

- pseudo gravity
- a fresh air cycle based on plant life.

A central cone-shaped area admitted sunlight to levels of lessening “gravity” for testing. The “forest” area is shaded in green.



Part 1: FIRST LOCATIONS

"SPACE OASES" as used in this article are defined as durable free space structures providing:

- artificial gravity through centrifugal force,
- closed life support system for air, water, and at least some food,
- shielding against long term exposure to solar and cosmic radiation and micrometeorites, and
- habitation for at least a transient community of people.

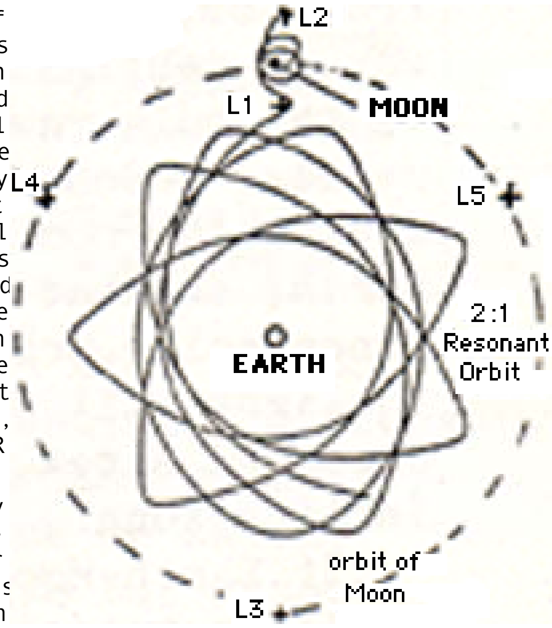
This is a more generous definition than "space colony" or "space settlement" which is conceived of as supporting a non-transient population of a size large enough (minimum 10,000?) to enjoy a respectable measure of self-sufficiency. We believe that smaller and cheaper space oases will pave the way.

Where in free space are we likely to find such oases for human life? Certainly in stable low Earth orbits (500 - 1000 km) where they will support manufacturing and processing, tourist, convention, education, and hospital functions. But for most of us, these close-in possibilities only whet the appetite for real breakout. Even geosynchronous orbit (37,500 km) fails to stir our space pioneering spirits.

The original “space colony” scenario outlined by Princeton physicist Gerard K. O'Neill, proposed a semi-stable area which trails the Moon in its orbit some 60° (about 5 days) behind in a sort of lockstep formation. Known as the 5th Lagrangian spot, or "L5", this location remains equidistant from the Earth and the Moon and is not difficult to reach. However, it is not as stable as once thought owing to per-turbations by the Sun.

It has since been found that a two week period highly elliptical orbit which would precess rather swiftly under the Moon's dominant influence, the so-called 2:1 resonant orbit, would not only be more stable, but easier to reach from the Moon (directly or via L2) and Earth. "L5" remains important as a Moon-synch-ronous loca-tion for communications relays, and as part of a long astrometric baseline together with "L4", but is otherwise a historical curiosity, good material for a trivia question.

A whole archipelago of space colonies at L5 was called for in a grand design to rescue an energy-starved Earth from a bottomless oil crisis. Unfortunately, there has been a very temporary respite in that crisis, but it was enough to squelch all political interest in this country which has raised short-term plan-ning to the level of an art. Interest in solar power satellites, the anticipated principal export of these space colonies, remains strong in the U.S.S.R and Japan.



Meanwhile, a 2nd energy gambit to a future space-anchored economy, mining lunar Helium-3 (600 times as abundant on the Moon as on Earth) to fuel a very clean form of nuclear fusion plant that would essentially emit no neutrons, is under serious study at the University of Wisconsin in Madison. Both scenarios require a permanent return to the Moon, but the export tonnage in the newer scheme is far less.

Yet a third possibility awaiting further dev elopment in high temperature superconduc-tivity is a girdle of Moon-sited solar power stations linked by superconducting cable so that solar energy could be beamed by way of relay satel-lites to all parts of Earth at all times of the month. Neither of these new energy schemes would drive substantial development of space colonies, settlements, or "oases". But any plan which calls for integration of the Moon into the economy of Earth will need at least some space-based manufacturing. Space oases will be built.

Once lunar resources form the major portions of Oases' import tonnage (not only raw materials but necessary provisions, etc. as well) -- say 90% to 95% or more -- it will be far more logical to site them in low lunar orbit (LLO). Since it is far cheaper to build and maintain equal habitation on the lunar surface *where everything is at hand and expo-sure to radiation is halved* (the lunar surface blocks half the sky), these manufacturing and construction camp oases will be occupied principally by production workers on tours of duty from their homes on the Moon where their families remain.

Since only production personnel are involved, and since what will be essen-tially dormitory space with condensed recreation facili-ties can be provided in sig-nificantly greater density, the productivity of such LLO oases per ton of structural mass should exceed that anticipated of the classical L5 colony by an order of magnitude (10) or better, making it far more economically viable. Since these workers would be adjusted to one-sixth Earth-normal gravity on the Moon, their construction camp oases would provide the same level. This is another enormous advan-tage since, given the sup-posed maximum spin rate of 1 rpm to avoid serious Cori-olis problems, the lower gravity facility can be built with a proportionately reduced radius and would be subject to propor-tionately reduced structural stress.

From LLO, finished products, even very large structures, could be sent on their way to destinations closer to Earth, just as easily and cheaply (if not more so) as the bulk raw materials from which they would be constructed. Nor is alleged reduced access to sunlight in LLO a real problem. Even at the equator, the boost available from lunar rotation is only nine miles an hour (compared to 1,000 MPH on Earth) so that positioning and launching to and from LLO oases in sun-synchronous lunar polar orbits along the terminator is no problem at all. Around the clock sunlight will be avail-able except during eclipses which equally affect L5 and other proposed sites. And higher lunar orbits would provide the same solar access at lesser inclinations.

If Earth-Moon tourism ever develops volume sufficient for it, a cycling cruise oasis or transitel (transit hotel) would allow first-class travelers to spend at least the major portion of their journey in comparative comfort and luxury. At each end, short and cramped shuttle trips would probably always be their lot. A more elaborate and specially equipped transitel might someday allow any emigrants to Mars a more tolerable sojourn.

Such a transitel would not be a grand resort but probably provide on board education for the settlers about Mars and the technolo-gies needed to render life possible there, and even assembly bays where they could assemble equipment that had been put aboard as parts to be used on Mars.

So much for the siting of space oases. Perhaps someday, space colonies in the now classical sense will be built, and the economic needs that drive their construction will determine where they are located. This we cannot now foresee clearly. - MMM

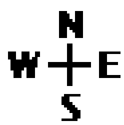
The original article is online at: www.asi.org/adb/06/09/03/02/011/first-locations.html

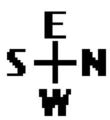
Part 2: Internal Bearings

EAST BY ANY OTHER NAME … “Spinward” and “antispinward” are common parlance for space colony enthusiasts. A prestigious author for some unclear reason coined these terms and they have been parroted ever since. Why is a mystery. On Earth, *which also spins,* “Spinward” is quite simply *EAST.* “Antispinward” is equally plainly *WEST.* There is no good reason not to transfer these familiar terms to the space oasis environment. Since it will be important that captains of incoming ships not be con-fused, the external convention that when facing East, North is to the left, will be preserved. This will result in an apparent reversal *inside* the oasis. That is, when facing East (the direction of spin), the wall *to the right* will be the North wall, etc.

The only other adjustment involved is for up/Zenith and down/Nadir. These are not quite simply reversed, since on Earth they are defined in respect to the *center point* of the planet, while on the space oasis, they will refer to the *axis line* of rotation -- not the same thing. Why is this? Because Earth gravity is inward toward the center of a *sphere.* Oasis gravity is not just outward, but toward the inner surface of a *cylinder.*

How can we expect to reach the public if we continue to use esoteric terms needlessly? “Antispinward” indeed! Give me a break! Repeat after me one thousand times: East is East, West is West, North is North, South is South. Now that’s not so hard, is it?

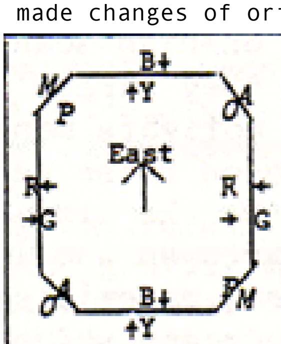




On Earth, custom gives the place of honor to North in both map legends and globe orientation.

On Space Oases, the corresponding legend will surely key on East.

The space oasis or colony provides simulated gravity through centrifugal force against the outside wall by spinning at 1 rpm, 1440 times faster than Mother Earth. This pro-duces exaggerated coriolis effects and prevents us from trying even faster rates for sustained daily activity. One of the things a first arti-ficial gravity facility in low Earth orbit (LEO) ought to determine is whether it makes a difference if work stations are set in the line of rotation (against a North or South wall) or perpendicular to it (against an East or West wall.) It may make no difference. But if it does, it may be advisable to provide subtle heading (vector) clues, for example by color coded strips at eye-height on buildings and room walls alike, that would alert the subcon-scious to the direction one was facing and automatically (learned instinct) adjust the way one made changes of orientation or movement.



Cue Color	Facing
Y yellow	East
O orange	NE
R red	North
P purple	NW
B blue	West
A aqua	SW
G green	South
M mustard	SE

Above is one possible arbitrary color-cue scheme (based on the well-known “color wheel”.) While color-cueing may not be critical to sur-vival, it could speed adjustment. Certainly, an experiment could do no harm.

Sports will be drastically altered by the “English” put on balls, etc. by coriolis effects. Orienting a court or playing field North-South would produce an entirely different “game” than with an East-West orientation. Experimentation will quickly determine which orientation will be standard for each sport. At the start of each game or match, opposing players or captains might toss not only to serve/bat/receive but also to see which side faces East, or North, as the case may be. Changing directions of play at halftime or between quarters would produce an even-handed game and the proverbial “level playing field.”

Some teams and players may be more adept at playing in one direction rather than in the other. If there is a league, with each team having its own home field, “home field advan-tage” would take on a whole new meaning.

Coriolis effects will make oasis sports far more challenging and difficult to master than corresponding sports on Earth. And, of course, it will be the young players who catch on more easily. At first the results are bound to produce slapstick play. But as players get the feel of this strange environment in which direction matters, and master it well enough not only to compensate for coriolis effects but also to take advantage of them, telecasts of inter-oases matches may rise to the pinnacle of popularity with armchair spectators on Earth.

Part 3: Space Oases, the Moon, and Different Drums

I have met space colony enthusiasts who look down their noses at those preferring plan-etary situations, as if they/we were mentally inferior, capable of believing any old none-sense (“flat-Earth” or “hollow Earth” types.) They pride themselves as members of a vanguard elite having graduated to a transcending view-point which rightly sees planetary prefer-ence as a leftover of some Neanderthal proto-mind. After all, simple mathematics shows that “Sun-space” could support population enormously more vast if the planets were dismantled to support construction of billions of space colonies!

But it is not just a question of adjus-ting to life on an interior surface as opposed to an exterior one. One must also be prepared to abandon nature-carved environments for ones totally man-made and artificial - great *zoo-scapes in the sky for people!* The strength to make such a transition does not come to every-one. Yet for some, this sacrifice will be easy. Either they are not vulnerable to the Sirenic wiles of natural beauty or they have the forti-tude to cast such temptations aside, confident that nature survives in the microscopic elements that make up even artifi-cial things. It takes an ability to be wholly satisfied and fulfilled by nature in little bits and pieces as afforded by planned land-scaping such as we see everywhere in urban and suburban places.

It could be that this new breed of person is at the forefront of human evolution, while those of us who yet feel the call of the wild, of raw and untamed nature, and who need occasional "fixes" by immersing themselves in surroundings not made by man, are relics of an earlier age, displaying some sort of mental tailbone. If we fail to adapt, do we not deserve to be bypassed, doomed to some developmental cul de sac?

It may be that those who cannot make the leap to total acceptance of the space colony vision are driven by silly misgivings, such as the fear that the inviting posters of colony interiors showing replicas of the Golden Gate Bridge and great pine forests are cruel hoaxes. After all, the demand for maximum utilization of limited space within each colony oases must inexorably crush all other considerations.

Or perhaps they/we fear that the promise of Athenian (direct) Democracy notwithstanding, space colonies may never succeed in casting off startup status as vast "company towns". Or might it be that some of them/us are antisocial and prefer a rural life such as may well be afforded by scattered inter-settlement sites on the Moon and Mars?

Perhaps they/we are addicted to star-gazing and cherish scanning the heavens at a more indolent pace than once a minute.Or do they/we harbor shameful suspicions that the very population pressures on Earth which motivate many to embrace the space colony concept will nowhere be more acute than on those very colonies themselves, transforming them from early Edens-Regained to the ultimate in stifling ghettos with no escape.

Some few of them/us may be eccentric artists and craftsmen who imagine some intangible advantage in being close to the source of the raw materials they work with. Then too, it may be the glorious megastructure concept which frightens some, being accustomed as they/we are to human settlements that add one abode at a time and continually redefine and reinvent themselves in search of youth. Such archaic throwback attitudes ought not to be lamented, however. One must accept that not everyone can be ancestral to the (space colony) future!

However, it serves no purpose to argue which of these two mentalities is the superior. Why not rejoice that there ARE people of both types FOR BOTH ARE NEEDED to develop the space frontier!

Those "risen above" planetary chauvinism have sketched scenarios in which the planetary bonds (such as the "degrading" lunar mines) are wholly teleoperated. But there is no need to to find ways to avoid condemning some people to life on the Moon so long as there are people, atavistic and misguided or not, who would cheerfully embrace just such an opportunity. It is not necessary for would-be space colony citizens to understand this strange caste, only to accept them/us as an alternate form of humanity and let them/us be happy in their/our own quaint ways.Someday we will *all* be grateful that there were, in our day, people up to the challenge of a rough and rugged frontier.

To borrow a phrase, *"Vive la difference!*

Moon Miners' Manifesto – # 12, February, 1988

A Pro-Breakeven Policy

by Peter Kokh < kokhmmm@aol.com >

[BREAKEVEN: the point at which the space pioneer returns as much value to the Greater Earth Economy (GEE) as he/she demands from it.]

The more remote "breakeven" is perceived to be, *the less likely* it will be that the steps necessary to bring it about are taken. "Breakeven" can be brought closer by reducing the amount of resupply needed to maintain each man-hour on the Moon or in free space by any and all possible means. An aggressive Pro-Breakeven Policy (PBP) demands pre-development of the technologies settlers will need to provide for as large a portion of their material needs as possible our of the resources to be found in naked lunar soil.*MMM* can serve no more important function than to stimulate such activities as will hasten that day.

Already mentioned [MMM #4 "Bootstrap Rockets] is perhaps the single most important project for a Pro-Breakeven Policy - development of a rocket engine to burn liquid lunar oxygen with powdered lunar aluminum, so that the cost of Earth to Moon imports (including personnel) is essentially reduced to the Earth to LEO cost, instead of some ten times higher. This is a *sine qua non* technology. If it stays science fiction, then *so does every-thing else!*

Already mentioned [MMM #4 "Bootstrap Rockets] is perhaps the single most important project for a Pro-Breakeven Policy - development of a rocket engine to burn liquid lunar oxygen with powdered lunar aluminum, so that the cost of Earth to Moon imports (including personnel) is essentially reduced to the Earth to LEO cost, instead of some ten times higher. This is a *sine qua non* technology. If it remains science fiction, then *so does every-thing else!*

Next in importance, and calling for guts government policymakers are unlikely to find, is an early decision to bypass the astronaut corps at the *start* of the lunar return project in favor of personnel willing to go to the Moon to stay and *not look back* to Earth and Clear Lake City. Sorry, but astronauts do *not* have the "right stuff" needed for *frontier building,* something quite different from exploring.

It's simple math. For every 150 lbs (c. 70 kilos) of replacement person sent to the Moon "base" 150 lbs of hydrogen (enough to make 1350 lbs of water using lunar oxygen) or of valuable capital equipment to mine and process lunar regolith soil and produce needed manufactured items could have been sent instead to boost the settlement resources and reserves.

Sending people *one way* to the Moon will require commitment and determination.

This will horrify politicians and many others, whose commitment to the Lunar project will ever be "tentative." The lunar initiative must be run not by those who intend to remain on Earth, but by settlers-to-be and their supporters, those determined to make it work.

When supplies and equipment must be sent to the Moon, the path of least resistance will thoughtlessly follow a "*coals to Newcastle*" policy: needless importation or co-importation (one-way containers) of items made of elements already abundant on the Moon, e.g. steel (iron), aluminum, and materials with a high oxygen content. Alternatives, admittedly more costly to fabricate on Earth, but enormously more welcome on the Moon, might be made of copper, tin, brass, duralumin (a 35$ Cu aluminum alloy), and polypropylene (C, H), etc..

To maintain morale, hobby activity must be allowed for And here, two birds can be killed with one stone by providing equipment for the "settlers" (let's not be afraid to use the word) to use in making homewares from lunar glass and ceramics, for example. Not only will this spare time activity contribute to "break-even" by reducing the list of goods needing to be imported, it will be a great boost to settlement spirits, and, by the creation of everyday visible items *made locally of moon stuffs,* will encourage a growing sense of *being at home on an ever less alien Moon,.*

The most difficult thing will be the first step, getting space enthusiasts to adopt a Pro-Breakeven Policy in the face of a deeply entrenched long-standing culture among space professionals and public policy makers that can only produce results quite the opposite. - PK

Space Oases Pioneers Quiz

QUESTIONS

1. What are the principal advantages touted for space colonies over lunar settlements?
2. Why are O'Neill cylinder colonies usually depicted as paired and connected at the poles b y cables?
3. How much more Nitrogen is needed in a sphere as opposed to a torus per person, all else being equal?
4. The proposed maximum of 1 rpm rotation rate puts minimum size limits on a space oasis. However, they may be built to larger radii at lower rpms. Is there anything which might motivate standardizing the diameter?
5. In a torus, the purpose of the spokes is a) to provide structural tension & support; b) to function as freight conduits for supplies and products to and from the exterior of the colony via a central hub; c) to allow people to travel to and from the zero g areas in the hub/axis; d) to cluster conve-nient highrise office and apartment comp-lexes at intervals within the torus inte-rior; and e) to serve as a short cut to the other side
6. How many O'Neill cylinders will it take to exceed the Moon's surface area?

ANSWERS

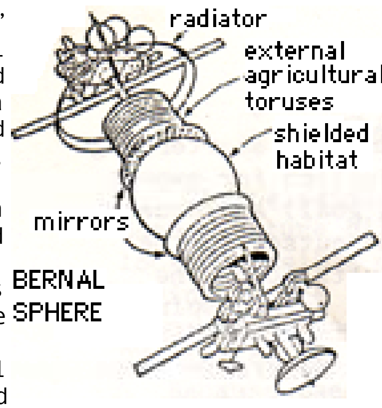
1. Three advantages are especially mentioned: a) The availability of full time sunshine; b) the freedom to select any gravity level desired, especially Earth-normal or 1 G c) ultimately, a far greater habitable surface area, given enough colonies -- if there is enough economic advantage in actual space development to support expansive outmigration from Earth.
2. A rotating cylinder tends to precess in its orientation in a surrounding gravity field, such as Earth's, just as a top will. If two counter-rotating cylinders are tied together, this tendency of their orientations to drift will be neutralized. This "elegant" solution is yet another instance of static thinking: mating two cylinders essentially for life. A more biodynamic alternative would temporarily pair one completed colony with another under construction which, when completed, would be set free to "reproduce"in like manner. The first colony would then begin construction anew on yet another offspring. This is the pattern in which many one-cell organisms reproduce in nature.
3. Assuming 1 rpm, 1G, I ATM of air pressure at standard mix, a density of 1 person/67.2 square meters (/730 sq. ft.) for both, the sphere would require 25.7 tons of nitrogen per person, the torus only 4.4. The sphere needs to import almost six times as much nitrogen per person! The cylinder would be somewhere in between, making the torus the most efficient in this one respect.
4. Because coriolis forces are so noticeable in centrifugal environments, and because their strength varies with the rpms, intercolony sports will only be fair to all if each colony has a standard radius and rotation rate as well as gravity level. There will be two leagues and no interplay between them: an Earth-normal league and a Moon-normal league. A colony which chose non-standard parameters would likely not be invited to join the league in its gravity class.
5. a, b, and c are all important, but *in that order.* d is purely frosting on the cake, an opportunistic usage. e is something perhaps everyone will try once, but as it will be disorienting and probably not save time, few will try it again, except thhe children.
6. An O'Neill cylinder with a radius of 900 meters and length of 9 km would have about 14 square miles of habitable area if you subtract for windows. The Moon's surface exceeds 14 million square miles. It would take a million O'Neill colonies of the size mentioned to equal that area. Starting at the rate of one a year, doubling that rate every year (an improbable goal) it would take 10 years to build the first 1023, and the millionth would be completed before the end of year 20. Such a rate of increased construction,workers, materials supply, energy etc. could never be maintained. This touted goal would likelier take centuries *if it could be maintained at all.*

SPACE OASES

Part 4: Static Design Traps

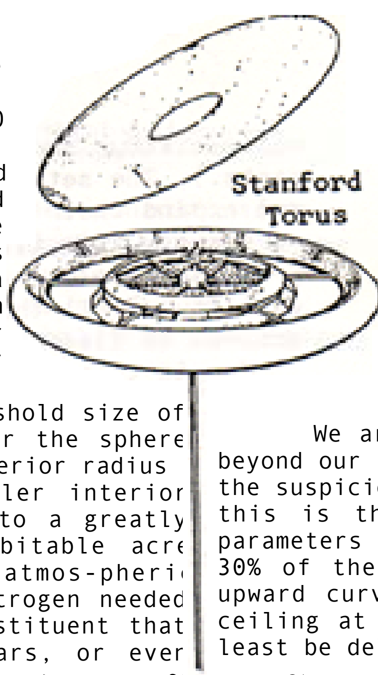
What is the shape of things to come in free space? The econo-mical torus or the great spherical and cylindrical megastructures with their sweeping world-at-a-glance views? These possibilities all have their partisans, often on purely aesthetic (subjective) grounds. However, work done before and during the 1977 Stanford design study workshop suggests some important advantages of the torus and corresponding disadvan-tages of the sphere and cylinder that will constrain real world choices.

The original “Island I” design proposed by Dr. O’Neill was the Bernal Sphere depicted above right. It would have had a circumference of one mile, had room for 10,000 residents and, to provide Earth-normal gravity, would spin at a rate faster than 3 rpm. It is now widely agreed that because of the physiolo-gical effects of strong coriolis forces, the maximum spin rate ought to be no more than 1 rpm. At that spin rate, a Bernal Sphere of the size proposed would have 0.3 gravity maximum. Thus a sphere of this size (or a hair larger) is a likely “starter” colony for those willing to live in a Mars-like gravitational field, and certainly (at a yet slower spin or even smaller radius) for those content with lunar gravity levels of 1/6th Earth-normal.But for those who insist on a full “G,” the Bernal Sphere at 1 rpm must be up-sized considerably to almost 3 and a half times the radius (a diameter of 3.5 miles) which would square the area enclosed and cube the mass and the construction materials needed, and have a capacity for 120,000 resi-dents at the same density. This is now hardly a “starter” project!



Superiority of the Torus

However,a torus of the same radius, rpm, and with an internal radius of 65 meters (about 420 feet wall to wall) -- the para-meters of the chosen Stanford Torus design -- would be sized right for 10,000 persons. By the same token, a Mars-gravity torus could be sized for 3,800, and a Moon-gravity torus for 1,600 (in both cases, keeping the 65 meter radius for the habitable interior of the torus.)



Nor is the much lower threshold size of the torus its only advantage. For the sphere and cylinder, the interior and exterior radius are the same. But the far smaller interior radius of the torus translates to a greatly reduced structural mass per habitable acre needed to contain a given atmos-pheric pressure. More, the amount of Nitrogen needed as atmospheric buffer gas, a constituent that must be imported from Earth, Mars, or even Titan at great cost, is obviously greatly reduced in the torus design.

But the list goes on! Neither the sphere or cylinder lend themselves to segmentation, and thus cannot be built in modular fashion. They are “megastructures”, “archologies”, which must be built all at once and which in the beginning will be underpopulated, then briefly just right, and thereafter ever over-populated.

In contrast, a torus can be built *two* segments at a time (two, because construction must always be balanced 180° if the structure is not to become eccentric in its angular momentum distribution.) As soon as a hub, two spokes and two segments are built -- essentially a barbell -- occupancy can begin.

Closable bulkheads are likely to be a relic as such segmented construction and this is a great safety advantage for it provides distributed vulnerability as opposed to the shared vulnerability (to catastrophic puncture or rupture) of the sphere or cylinder. Yes, the torus can also be built all at once, if reck-lessness has the upper hand.

The point is that a segmented approach reduces the threshold of habitability to a third (a pair of 60° wide segments) or less (smaller starter segments.) The settlers can move in and set up shop and begin production for export and expand their wordlet to a full torus (the “imago” or design goal) as success warrants. This flexibility will be of especial importance at the outset of the free space colonization venture, when there will still be many doubts about the validity of all the paper studies, and while the financial backers remain spiritual natives of the State of Missouri.

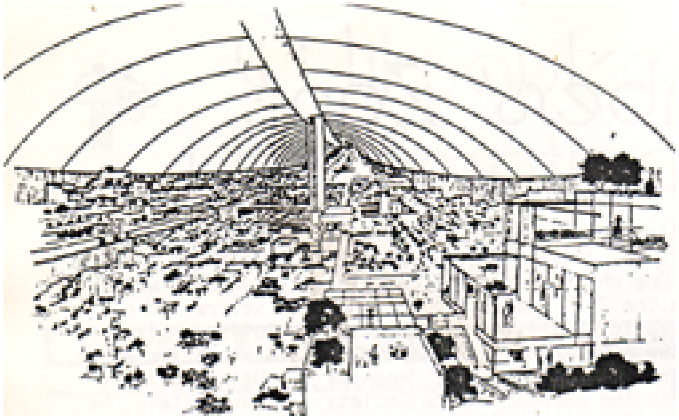
Consider, what is a “world?”

Nor is this all! Surely the most Sirenic feature of the Bernal Sphere or “Sunflower” Cylinder is the spectacular sight of the whole worldlet in one pan from wherever one is situ-ated insight. But just as in Homer’s *Odyssey*, this feature is a siren that lures the unsus-pected into a psychological whirlpool.

It is customary to define “world” as a total or integral theater for human life. But that is an incomplete definition.

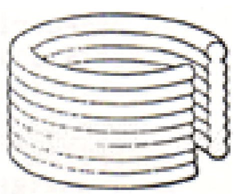
“World” also denotes a conti-guous set of life-spaces *only a small portion of which is within sight or above the horizon at a time.*

We are used to *most* of the world being beyond our survey at any given moment. There us the suspicion, felt by the Stanford group, that this is the healthier situation. Given the parameters of the Stanford Torus, no more than 30% of the torus would be visible *below* the upward curving horizon provided by the torus ceiling at any one time. Cabin-fever would at least be delayed or mitigated accordingly.



It is the likeliest scenario then, that the real world “Island One” will begin as an expandable barbell able to grow into a full torus if the economic expectations of space development are proved out. This low-threshold foot-wetting is far more likely to see the light of day (than the original “Island One” -- the Bernal Sphere) given the conservative nature of venture capital.

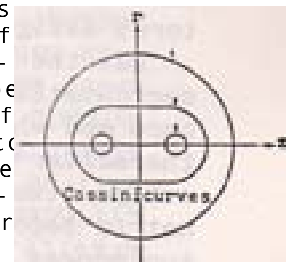
But this is only a beginning. Can such a beginning lead somewhere? As designed in the limited ten-week time frame allowed the 1977 Stanford Study participants,the torus seems a dead-end, incapable of growth, due largely to the solar access system planned for it which involves a large unitary free-floating mirror (at an angle above the torus in the illustration top left.) The mirror’s purpose is to direct sunshine through chevron portals into the interior of the torus. I can just see this mirror suddenly shattered or dislodged and floating away in some accident waiting to happen! (The Island III cylinder’s “sunflower” petal mirrors, subject to up to 6 Gs at the tips, whirling through space at over a thousand miles per hour, tied to the cylinder itself through cables, seems even more fate-tempting!) But the point is that this system does not allow the torus to expand easily by adding extra bands or clones, side by side.



BANDED TORUS

A banded torus could expand to constitute a worldlet of the projected population capacity of the sphere or cylinder. The banded torus, *if an alternate solar access system were developed,* would still have some less than ideal features. Each torus band closes in on itself, biting its tail. While an improvement over the sphere and the cylinder in many significant respects, each of its bands is an all too tiny world unto itself. As a whole, a banded torus would be over-compartmented disjointed whole promoting excessive neighborhood loyalty at the expense of any at-large settlement identity: an open invitation to fiefdom politics and unhealthy rivalry between band bosses. I might take external threat to encourage cooperation.

But why dwell on space opera plots if there is yet another choice? Whoa! you say. The barbell, sphere, cylinder, and torus are the *only* possible three dimensional balanced forms allowed by rotation of the appropriate subset of Cassini curves. Such is the *Ivory Tower* belief of the all too common mathematician-engineering type who would not dream of crossing disciplines to sully themselves with the dirty examples to the contrary provided by Mother Nature in happy abandon.



What is more important? Professional superiority complex of bursting open the barriers to free space settlement? If biology suggests a bypass of the Cassini impasse, I say let’s have a look. So dynamic an idea as free space settlement is inappropriately hamstrung by *STATIC DESIGN TRAPS.*

Space Oases Part 5: A Biodynamic Masterplan

The Ivory T ower at its Worst

If those involved in space colony design to date had been consultants to Mother Nature billions of years ago, *none of us would be here today.* For one over-looked possible derivation of the Cassini curves is generated *quite simply* simply by moving figure 3 [above] *along* the r axis as well as around it. This elementary innovation provides the dynamically balanced *double* helix of venerable DNA antiquity, genetically radical to life as we know it.

Exploring the Helix Architecture

Because the helix is double, it can grow indefinitely at tips 180° apart and always be stable. [To construct a crude model, take two thick helical springs with gaps about the same size as could thickness, spray paint one a different color, and intertwine them with end tips diametrically opposed.] The double helix has the same starting point (conceptual and construction-wise) as the torus: the barbell; but its growth is canted either North or South as the segments are added so that when a half-whorl is completed, it lies adjacent to the start of the opposite whorl and so on. The result is a “twin valley” system which can be extended indefinitely apace, creating a larger, and most importantly, an *open-ended* worldlet.

A dozen double whorls of the same parameters as the Stanford Torus would provide, in a space a little more than a mile wide and a little less than two miles long, two valleys, *each forty miles long,* and room for a quarter million people. The two valleys of a Double Helix Oasis or DHO could be similar or one could be given to a residential centered mix of land uses, the other to a commercial-industrial centered mix.

A *triple* helix starting with a “Y” shape 3-armed dumbbell with arms and growing points 120° apart is another possibility, which would allow time zones eight hours apart for the ideally “fair” three-shift work system. This would allow factories and schools and other facilities to be used cost-effectively around the clock, all manned by persons on their own personal “first shift.”

The DHO spokes would line up in opposing pairs "hand over hand" fashion along the central axis, maintaining structural integrity. This extends the comparison with the architecture of the DNA molecular structure. One pole of the axis would serve import-export functions, the other, continued expansion. At the original starting end, the twin coils could be extended vertically pig-tail fashion to the axis, allowing graduated adjustment zones to and from lower gravity levels for immigrants and emigrants as needed. This. of course, would effectively close the interior "bay" at one end -- a choice which would, I suspect, have more pluses than minuses.

A significantly greater greater fraction of a DHO interior would lie beyond the horizon. In the sample twelve double whorl metropolitan colony sited above, no more than 1.25% would be visible from any one vantage point, while still offering vistas of the order familiar to Earthside city-dwellers. Certainly this would provide a much more *worldlike* situation!

Life Expectations for Oases Youth

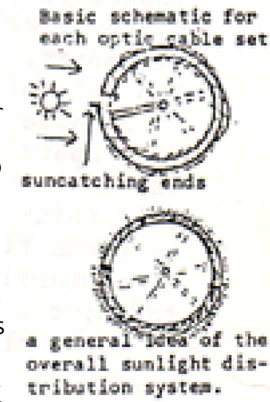
Children born in a DHO or THO, could grow up assured that they could continue to live out their lives, if they so choose, in their familiar *growing* homeland, rather than being forced to migrate to a new colony because their parental one was already at capacity. To be sure, expansion might someday reach a point at which further growth would be seen as undesirable, but then limits in one form or another will always act as gravity to human spirits. For sustainable mental health, the DHO or THO is the only choice. The Bernal Sphere, Sunflower Cylinder, and Stanford Torus might be "great places to visit, *but you wouldn't want to live there!"* Perhaps these classic space settlement designs are best suited for use as resorts or even "national parks" -- places to visit, not to live in!

Design Challenge: Sunlight Delivery Systems

The big design obstacle to the DHO or THO -- as well as to any banded torus -- is the perceived difficulty in furnishing adequate ins<u>o</u>lation: solar access to all parts, bringing in the sunshine! I say "perceived" difficulty, because it results from an unnecessary restriction to a mirror delivery system.

In conventional space oases designs -- sphere, cylinder, torus -- some two meters or six feet of fused lunar oxides surround the exterior as shielding against radiation, solar flares, and micro-meteorites. This shielding is co-rotating and attached, except for the Stanford Torus in which it is immobile, separated frown the rotating exterior surface of the torus (relative speed is 205 mph) by a gap which hopefully would be main-tained by some sort of failsafe system. In either case, the shielding mass serves no additional function and is seen as but a handy repository for that fraction of imported raw lunar soil not actually used for other construction or manufacture -- tailings residue.

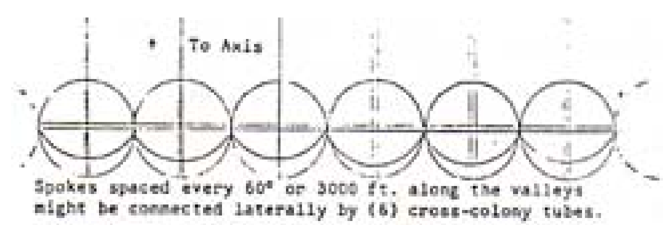
Such a solution is not as elegant as it might be. ["Elegance" can be defined as the killing the most birds with the least stones.]



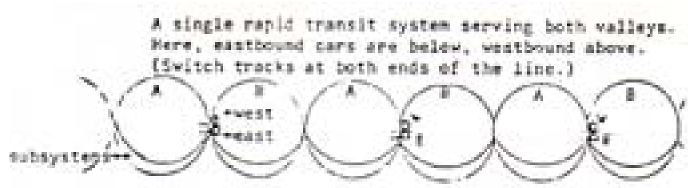
Instead, at least a major portion of this sheilding mass could consist of fiber optic cables. At each point along the exterior (the axis of the DHO or THO would be perpendi-cular to the Sun and not pointed at the Sun as in the mirror-using designs), the sunlight catching ends of a *set* of strands of varying lengths would point outward. As construction proceeds, optic cable coils originating at various points would be unwound in a bias ply pattern with the ends of many coil-sets entering the colony at each point along the ceiling curvature to distribute sunlight evenly throughout the whorls. This should not inter-fere with periodic lateral openings from one valley to the neighboring one. Such a sunlight delivery system is modular, expands apace with the colony, and contributes tensional strength to the envelope *as well as* contributing a major portion of shielding mass. It would be less subject to catastrophe than any mirror system using a combination of great outrigger mirrors (with high angular momentum) and cumbersome, structurally suspect, chevron panels. The degradation on the optic fiber system over time due to adverse exposure would befall other systems as well, and is a challenge (design, materials, changeout facility -- or all three) that needs to be addressed.

Escaping the Static Design Trap

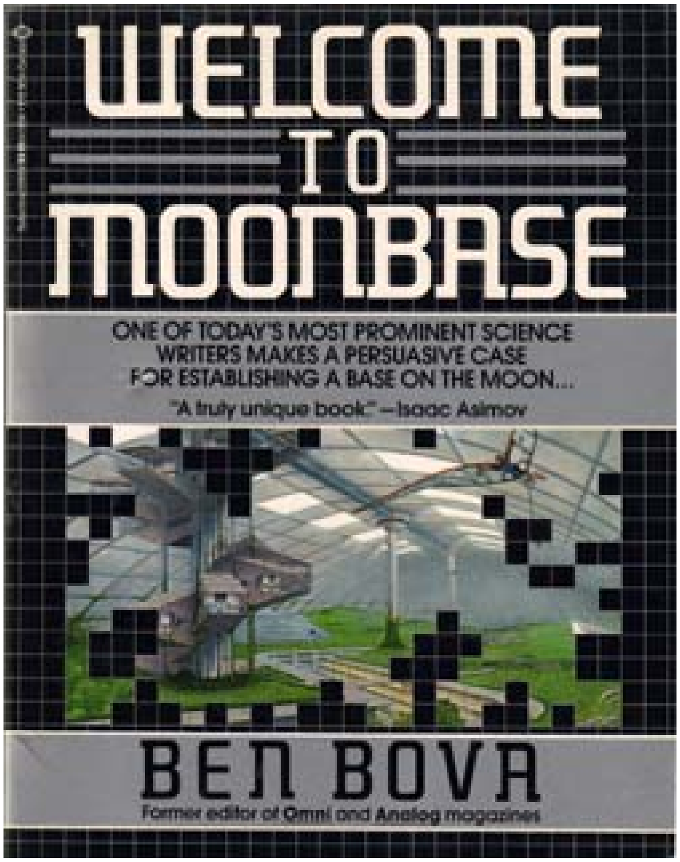
The Double or Triple Helix Oasis plan is offered here as a way out of the static design traps inherent in the torus, sphere, and cylinder. It is a concept which has benefited from only one person's input and is hereby thrown open to constructive criticism needed to bring it to design maturity. It is the only oasis plan that would provide an environment in which I can picture myself without unendurable restlessness.



Above: The trasportation Grid of a DHO/THO



Above: A single rapid transit line, mounted inj the sidewall of just one valley in a DHO would link the entire growning complex.



An oversize (7.25"x9.25") paperback released November 1987 by Ballantine (#328590) $9.95 ISBN 3- [as of 2004 no longer in the inventory of either Amazon.com or BN.com]

Review by Peter Kokh

A book like WTM could hardly be more timely. *Not a novel,* (you will not find it in the science-fiction racks, look instead in the Nature/Science section, and if the store does not have it, *order it!* ,) this is a mixture of fact and what the author perceives as "future-fact" into a "plausible account" of what one might expect to encounter as a new recruit of Moonbase, Inc., a multi-national, government-enterprise consortium that runs a 2nd generation Moonbase in the 2020's. Indeed it is written as a company manual for new employees signed up on Earth.

There are several B/W illustrations and six full-page color glossies by Pat Rawlings of Eagle Engineering in Houston. This artwork is shared, interestingly enough, by Lady Base One Lunar Development Corp. and the concepts behind Bova's plan and that of William F. Mitchell bear strong affinity. While the NSS board has so far been cool to the notion of cooperation or association with LBO, it is clear that NSS President Bova's thinking follows a path closely akin.

Moonbase is situated inside the large central nearside crater *Alphonsus,* also the scene of Bova's *Grissom-Komarov,* the side-by-side American-Soviet base that declares its independence in his novel *Millennium.* Alphonsus is the location of well-documented TLP, Transient Lunar Phenomena events, specifically short-lived reddish glows thought to be caused by episodes of outgassing (Bova, fingers crossed, suggests ammonia and/or methane because these gases would be invaluable if present in economically harvestable amounts; but this reviewer expects carbon monoxide, sulfur, or radon.) Alphonsus is quite prominent in a small telescope either at first or second half moon (quarter.) Mining operations are carried out beyond the crater's west wall in nearby Mare Nubium, the Sea of Clouds.

Bova's vision includes one of the things called for in past issues of MMM, e.g. hybrid rockets powered by powdered aluminum and liquid oxygen [see "bootstrap Rockets in MMM #4] and development of full-scale manufacturing on the Moon as opposed to simply mining and exporting raw materials (as called for in O'Neill's space settlements plan.) He also foresees, correctly, we think, that L1, the Lagrange point between Earth and the Moon) and LLO, Low Lunar orbit, will eventually eclipse LEO, low Earth orbit, as the logical primary space-based manufacturing locations.

There are some things we did not like.

- Despite the emphasis placed on the importance of recycling and biosphere integrity, there is an all too casual permissiveness of smoking and the use of plastics
- Research is done on the Moon that could have been done on Earth (ideal trade-of point between natural sunlight and all-artificial lighting for crops) so as not to delay things on the Moon
- Recruits are encouraged to bring plants (which could be infested) instead of seeds
- Accommodations are skimpy (100 sq ft per person, 175/couple)
- The Earth Calendar is used with an annual Christmas-New Years cross-country race (sometimes this would be during sunup, other times not
- He assumes (Siberia-style) that to get recruits, Moonbase must offer "the best pay and benefits in the Solar System"
- Recruits come for a year at a time, can re-up for a year at a time, up to five years total, at which time they can apply for permanent residence, perhaps too conservative a settlement plan

here are also, despite previewing of the manuscript by several "authorities," some major goofs.

- The Mass Driver is 4 km long, obviously using MD II technology, now long superseded by MD III technology requiring a launch track only a few hundred meters long.
- He speaks of the Moon as the site of "the largest fully steerable radio telescope in the solar System, some 295 ft (90 m) in diameter, when there is already, for some time now, a larger one on Earth in Bonn, West Germany (100 m or 328 ft.)
- He anticipates 1000 cm (394") reflecting telescopes on the Moon when larger ones are already in the planning or construction stages on Earth in several locations.

- He anticipates 100 cm (10 m = 394") reflecting telescopes on the Moon when larger ones are already in the planning or construction stages on Earth in several locations.
- He mentions the lunar month as 27 days long. This is true if you reckon by the stars, but totally irrelevant. The only pertinent measure is the length of time between one sunrise and the next at any given location and that is 29.5306 days.
- Bova also has visits by the Bolshoi Ballet and the Nova Dance Theatre of Halifax to lessen the monotony of routine at Moonbase. Earth singers and actors, yes. But dancers? I'm afraid they would be quite clumsy and awkward in 1/6 G without months of acclimatization, practice and re-choreographing their steps.
- The worst mistake, however, is assuming the need for the expensive import of tons of liquid nitrogen to cool the Mass Driver's superconductors when on hand liquid oxygen has a temperature only 13 Kelvins higher. I'm sure that modest advance in superconductors (compared to the 73 Kelvin leap already realized from the temperature of liquid Helium (which *could be harvested from the solar wind gasses adsorbed to particles in the regolith*) will long since have been accomplished.
- Grating to me personally, but probably not bothering other readers, is Bova's coinage of *Luniks* for permanent residents. Does one speak of Iowiks, Alaskiks, Nevadiks, Angoliks, Cubics? The obvious suite to the commonplace paradigm [Roma>Roman] is [Luna>] *Lunans!*

"Two Thumbs Up! "

These complaints, however, are not meant to fault this book's merits which are considerable. Bova clearly expounds the principle motives for a Return to the Moon and Use of Lunar Resources.For those who have not been following the constructive discussions of the past few years and the growing consensus of those who want to see mankind expand into the Solar System at large, this is an excellent book. I recommend it highly for your personal bookshelf, and even more strongly as a gift to those open to reason but not yet belonging to the choir. Indeed it is for these that Ben Bova has aimed his manual. WELCOME TO MOONBASE deserves wide distribution, and the causes we all hold dear will be greatly favored by generous circulation. Buy at least two copies. One for your self, and another to give. It belongs in every school library - PK 1/88

Moon Miners' Manifesto – # 13, March, 1988

Artificial Gravity Quiz

Questions

1. Will an approaching shuttle craft find it easier to dock at the hub of a spinning space oasis or at the rim?

2. If anything *has* to be vented from the oasis, where will be the best place from which to vent it?

3. L5 at this future time is just a construction site, but tourist ships from Earth and from the Moon visit it anyway to take in the grand sight. What's to see?

4. Why is the "erector set" boom the most expensive part of the current NASA space station design? And would this same consideration affect a boom for a spinning barbell shaped artificial gravity facility?

5. If at 1 rpm, the required radius of rotation to simulate Earth-normal gravity is about 900 meters, what would be the required radius of a training facility for volunteers to crew an aerostat/balloon laboratory in the upper reaches of Jupiter's atmosphere?

Answers

1. the conventional wisdom is at the hub. To dock at the rim would take perfect timing, leaving no room for error. *On the other hand,* docking at the rim will not be the straightforward maneuver one might expect. Whether the hub-port co-rotates with the oasis (as in the film *2001: a Space Odyssey,* making it necessary for the shuttle to match spin rates -- and axes of spin -- before nosing in) or whether the hub-port does not share the general rotation, there is an overlooked factor that could be very troublesome. No matter how carefully the oasis has been or is being built, with attention to diametrically balancing both exterior shell and interior structures, it will be difficult to keep the *actual center of mass and artificial gravity* lined up precisely with the physical hub-port structure. Add ongoing movements of personnel and goods within the station, and there must be a non-zero residual "wobble." To the incoming shuttle pilot, the hub-port will appear to oscillate eccentrically once a minute. If this wobble can be kept to under an inch - a tall order -- docking will only be bone-jarring. More than that, and it might be impossible. *"Passengers will keep vomit-bags handy!"*

2. The rim, where centrifugal momentum will carry the substance away from the oasis on a tangent. Anything vented at the hub will tend to hang around, adding to a hub-hugging fog.

3. Perhaps the most beautiful sight this side of the Moons of Saturn: the twin worlds, Earth and Moon, suspended together in space 60° apart, an ideal compromise between too close (to take them both in at one stereoscopic glance) and too far (to see the usual naked eye detail). The Moon will appear the same size as seen from Earth, Earth the same size (3.7 times as wide as the Moon) as seen from the Moon, and sixty-some times as bright, phase for phase. The two will show phases some 60° out of sync,

and watching this celestial *pas de deux* through a four week phase set will be a once-in-a-lifetime dream.

4. In LEO, low Earth orbit, the space station will transit from sun to shadow and from shadow to sunlight every 45 minutes or so. It must be prevented from flexing as it warms or cools alternately lest the micro-gravity sensitive work inside the station be disturbed. This could have been arranged by loosely wrapping all the boom elements in crumpled foil, but NASA chose to develop a special composite with zero-coefficient of thermal expansion (great for spinoff but tending to financially preempt further space achievement steps.) This sensitivity will not be important for an artificial gravity facility.

5. Gravity at Jupiter's cloud deck "surface" is about 2.7G, so the training facility will need a radius of 2.4 km (1.5 mi.) at 1 rpm.

Space Oases Part 6: Back at Square One: Baby Steps with Artificial Gravity

by Peter Kokh

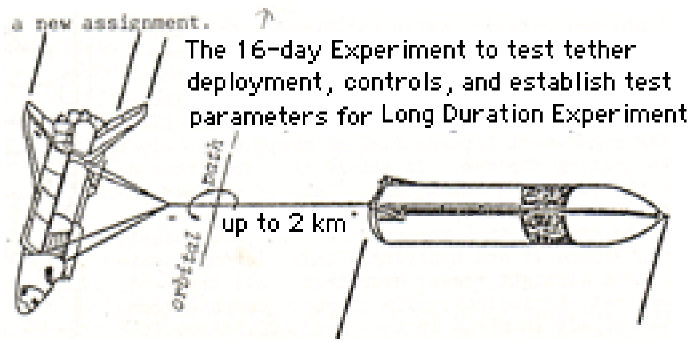
I remember my somewhat bitter disappointment on first seeing early NASA proposals for a space station. Where was the great wheel? Didn't *they* want artificial gravity? How could they take so lightly the great visions of Tsiolkovsky, Noordung, Von Braun, Clarke, and others? At first the answer seemed to be that the purpose of this station was to allow micro-gravity research in materials processing, and this would, of course, rule out pseudo-gravity.

However, there are more profound considerations why our first station could not be a rotating one. To induce full Earth-normal gravity, all the early, now classic, designs necessarily counted on a much higher rotation rate allowing a correspondingly smaller radius, than we now feel humans can reasonably be expected to endure on any sort of long term basis. At a more reasonable and leisurely 1 rpm the radius of a full Earth-normal gravity providing station must be on the order of a discouragingly large 900 meters, more than half a mile. Such a reality check requirement renders the traditional torus/wheel a development well into our future.

But what about reducing the torus to its barest essence, a rotating barbell? Even this, on the scale necessary, would be an ambitious way to start. Yet, if we wanted artificial gravity bad enough, it shouldn't be that difficult a challenge. Sooner or later -- *far better sooner than later* -- we *must* get our feet wet with artificial gravity. Too much depends upon it. Will humans, plants, and animals thrive indefinitely at such mid-gravity levels as the 0.38 G of Mars and the 0.16 G of the Moon? If so, how much lower is the threshold above which physiological deterioration will level off on a plateau we can live with? Will the 0.03 G of Ceres be sufficient? Will we be better off providing artificial gravity on the six to nine months long journeys to and from Mars? And what is the minimum radius/maximum rpm that will be suitable for a *general population* environment such as on a free space oasis or settlement?

There is no reason why our first experiment with artificial gravity in space cannot be arranged at quite low cost within the next two years.

NASA has already agreed t o begin flying the External Tank to orbit *on request.* Studies have already outlined the possibility of releasing the External Tank on a thether, inducing rotation into the Orbiter-tether-Tank "system" in the plane of ihe orbit and simultaneously releasing the orbiter at the bottom of the swing so that it de-orbits without the usual burn, while the External Tank is released at the top of the swing to coast into a safe higher "parking orbit" to await retrofitting for a new assignment.



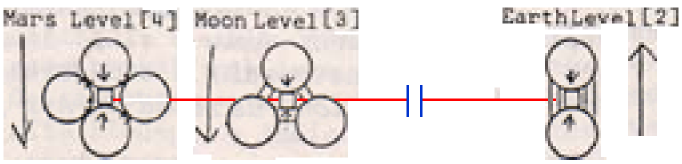
A much more limited but similar test was carried out in September 1966 on the Gemini !! mission in which Richard Gordon, in an EVA,fastened a tether from the Gemini capsule to the Agena 11 rocket after the later had been used to boost Gemini into a record 850 mile apogee orbit.

If the tether can be reeled in or out to say 2 km, the Orbiter and External Tank combo could afford experimentation with varying radii and rpms and gravity levels over the length of an Orbiter mission, at first, no more than eight days, but eventually up to sixteen days if the extended duration capability that NASA now wants is approved, as is likely, since it was a Congressional idea. [This capability will be available at an estimated $126 M about 45 months after project commitment.] Since this will be a temporary rotating system with the crew already aboard and resupply unnecessary, docking and undocking need not be addressed,

While such a short experiment -- even at a maximum 16 days -- will not answer questions about long-term physiological and biological effects, it should allow us to document current expectations about what the design parameters -- radius and rpm -- should be for the first long term facility. If, for instance, a 16 day mission shows no problem with say a 1.5 rpm rate, this would be extremely important.

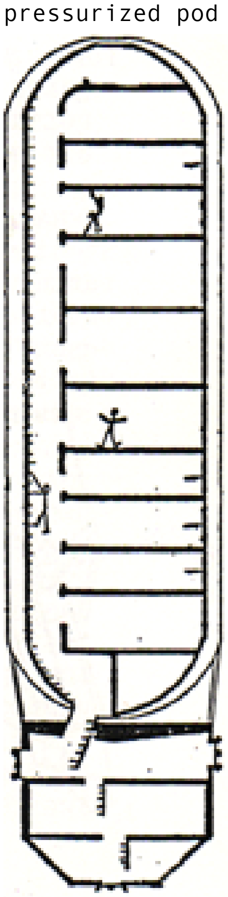
Given the minimal development & mission costs of this entry level experiment in artificial gravity, and the importance of this concept basic to all space development scenarios, the National Space Society should, without delay, adopt strong advocacy of such a demonstration.

Moving Beyond -- what should be the minimal design requirements for a long-duration artificial gravity facility? I would think, considering mankind's future ambitions, that we should be looking at a barbell arrangement that balanced an Earth-normal habitat/lab at one end with Moon-normal and Mars-normal facilities at the other. Our "sub*orb*an tri-level" should have ample space to test effects on plants, animals, and humans, with the necessary lab equipment.

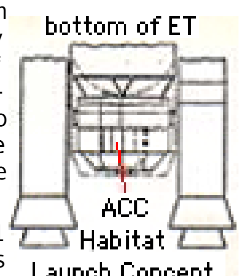


Arrangement of the Clusters of habitat/Lab Units seen from above (along the boom). The large arrows show the direction of spin. The small arrows show entrance to the commuter pod traveling inside the boom.

The expectation would be that, baring unforeseeable emergencies, a crew could remain aboard for a year or two without relief. Therefore the crew could be put aboard prior to spinup and taken off after spindown. Thus docking facilities need only be provided for consumables and volatiles that can be pumped through conduits (or moved on snag-proof conveyors through same.) Visits between the three gravity levels could be provided by a pressurized pod traveling through the boom.



As to the habitat/lab units themselves, we could combine a sparingly appointed liquid Hydrogen tank (lower 2/3rds of the ET, 97 ft. long and 27.5 ft wide and twice as spacious as Skylab) with an elaborately equipped Af Cargo Compartment module to ride into space just below the External Tank.

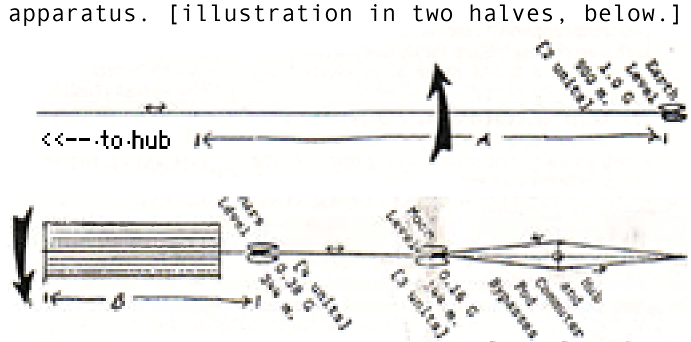


Putting all the electronics and laboratory equipment in the ACC would minimize the retrofitting task for the emptied hydrogen tank. As to the tank, I find suggestions of inflatable floors and dividers a little humorous when a simple alternative can be pre-built into the tank with zero effect on its fuel-feeding performance: floors, walls, shelves, and stairs or ladders out of aluminum grating *through which* the LH2 would flow with ease. Once in orbit, it could be quickly retrofitted with a simple wiring harness and flexible plumbing. "Carpets" could be unrolled on grating floors, blanket tapestries hung on grating walls for privacy, and sleeping bags moved in. On the experiment floors, biology trays need only be carried in and set on the grating shelves. It should take less than a day for the crew to make the tank *home sweet home*. There is no need to be more elaborate than this< if we put all the complex stuff in the pre-outfitted ACC.

Extra insulation could be applied from the outside perhaps by simply unrolling fiberglass batts around the tank and applying a thin micrometeorite shield (does not need airtight seams) over that. All the hard-to-install equipment (medical, biological, life-support, computer/communications etc.) would already be in place in the "dry" ACC before it left Earth.

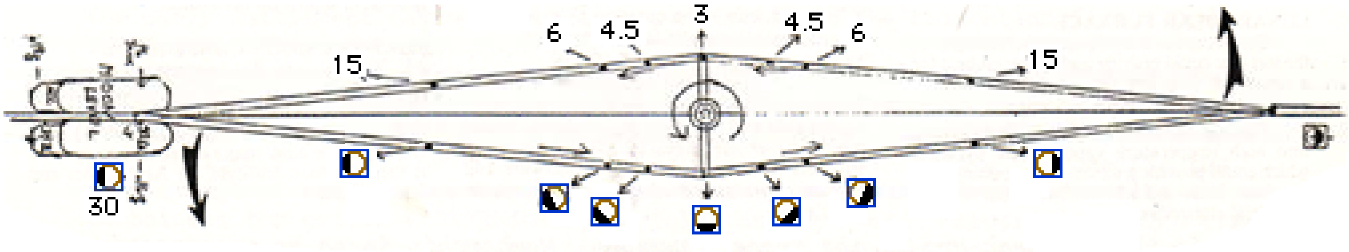
How do we ballance this orbiting teeter-totter? Neglecting the boom for a moment, we find that quite conveniently, two of our LH2/ACC units at the Earth-normal end are perfectly ballanced in angular momentum by three such units at the Moon-Normal level and four at the Mars-normal level. Assuming the radius at the Earth-normal level is 900 m. at 1 rpm, the Lunar facility will be centered at 144 m past the hub on the other side, and the Mars complex at 342 m. from the humb, down the boom from "Litttle Luna." [How much space is ideal at each level does not enter into the equation. That "Mars" gets the most space is an opportunistic result of neutral mathematics, and not of personal preference.]

The greater boom length with its attendant angular momentum on the Earthlubbers end [A] can be counterweighted by extending the opposing boom past the Martian facility and using it as support for an appropriately sized Solar Power Panel [B] This panel could be slide-mounted to act as an adjustable ballast to keep the overall structure's axis of rotation centered on the physical hub/docking apparatus. [illustration in two halves, below.]

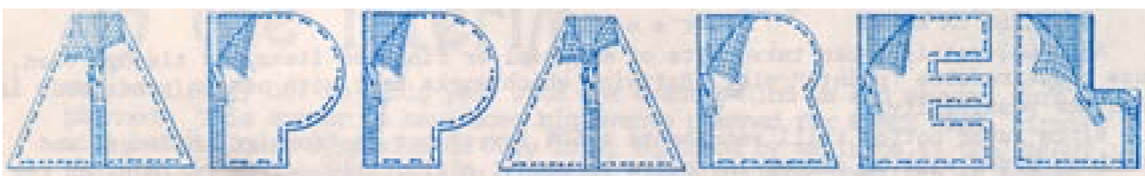


Travel from one side to the other *through* the hub necessarily introduces a moment of chaotic disorientation. For this reason the boom splits in the middle ("Cislunar") section to straddle the hub, 14 m. to either side. The commuter pod has a weighted pressurized squirrel cage compartment that neatly swivels to remain plumb to the local up/down vector. By skirting the hub, the occupant(s) will maintain some weight at all times and experience no sickening topsy-turvy period. This is shown in the diagram below with the floor of the cage shaded in black and the "weight" felt by a 180 lb. person at each point is indicated.

One would always travel to the East (Spinward) of the hub to maximize this effect.



This modest Tri-Planetary Simulator needs just nine (9) ET Hydrogen Tanks and ACC units. The LOX tank and intertank are not used in the plan and can be assigned other reuses such as for a co-orbiting fuel tank farm, etc, As such it is not inherently difficult nor expensive by current standards. The LH2/ACC units, if standardized, should cost significantly less than planned Space Station modules. The shuttles that ferry them to orbit can also bring along on the same missions, the following items carried in the Orbiter payload bays: boom materials, commuter pod(s), solar panels, and the modest retrofitting items needed, etc. These requirements sum up as a less expensive project than the current NASA planned micro-gravity “Space Station.” Moreover, they would put in place an element that is urgently needed if we are indeed serious about permanent emigration past low Earth orbit. <MMM>



EVERYDAY AND OCCASIONAL *[made on Luna]* CLOTHING FOR THE EARLY SETTLEMENT

by Peter Kokh

PROHIBITIVE COST of imported clothing: the need to maximize “lunar content”

When *token* humans first return to the Moon, their clothing will come with them and be resupplied from down-the-well as necessary. Once the limits of the beachhead are burst and settlement begins in earnest, it will become necessary of success to cut avoidable upports to the bone. What about clothing?

The most important consideration is fabric content. Only fiberglass with currently limited apparel applications is totally Moon-sourceable. Baring (and/or until) discoveries of and access to sources of supposedly Moon-exotic elements such as hydrogen (H), carbon (C), and nitrogen (N), fabrics which contain the smallest proportion of these in comparison to Moon-sourced oxygen (O) will be the cheapest to manufacture on location.

Most synthetics besides rayon consist of H, C, N, and even chlorine (Cl) almost exclusively, and there will be *no advantage to making them on the Moon.* Indeed, considering both the amount and nature of the waste byproducts of their manufacture, such fabrics are *most cheaply made and imported from* the source worlds of these elements: Earth at first, then possibly the Martian moon Phobos, or an Earth-crossing or Earth-approaching carbonaceous asteroid. Without growth-defeating subsidies, such fabrics as nylon, orlon, dacron, acrylic, polyester, etc. will be quite expensive compared with Moon-grown cotton, especially since they are not biodegradable or recyclable (except through incineration with attendant nightmares for small biospheres) and represent possibly permanent “banking” of these precious elements - permanent withdrawal from the mini-biosphere. The early settlement might well put such synthetics on the contraband list. Does the frontier begin to look “rough?”

COTTON to the rescue?

Fortunately, cotton is still the most versatile and *comfortable* fabric known to man. It can be made into many forms: broadcloth for shirts, muslin and percale for bedding, flannel for shirts and nightwear, velour and velvet and chintz for upholstery, terry for towels - the list goes on. before you breathe too deep a sigh of relief, however, be aware that some of our modern processing techniques for cotton will probably be taboo on the Moon. *Mercerizing* which treats cotton yarns or fabrics with caustic alkali under tension, in order to increase its strength,,luster, and affinity for dyes is an example. It renders cotton less biodegradable. Modern *colorfast dyes* are derivatives of coal tar and both in themselves and in the application process, “contaminate” the fiber further. Not all bleaches are ecology friendly. Where does this leave us?

Taking Clues from Earlier Frontiers

Settler resourcefulness with cotton will not need to start from scratch. We need only to turn back the clock to an earlier age for a whole litany of ways to treat and embellish cotton wear. To start with the seed fiber itself, not all strains are the same natural white. Egyptian cotton is rather beige or tan in hue. By including several strains of cotton, a natural cotton-palette of shades could serve as a starting point. Might genetic engineering come up with cotton pre-dyed with such natural colorants as indigo (denim blue), henna (red-orange), chlorophyll (green), etc.? This would be a useful and ecologically responsible line of experimentation. If we began experiments now, we could conceivably make a lot of money in the terrestrial "green" market among the growing numbers of environmentally aware consumers.

Where bleaching is desirable, gentle bleaches such as prolonged exposure to sunlight, or more probably, (with less side-effects injurious to the fiber) hydrogen peroxide (H_2O_2), a cousin of water. Vat dying of the yarn or finished fabric or item can be with done with biodegradable indigo, henna, and other naturally occurring vegetable pigments. Lessened exposure to sunlight, and more extensive use of sonic laundering methods might prolong the half-life of these gentle colorants

At home, settlers can take bolts of material or finished items and tie-dye them, use biodegradable "paints", etc. Batiking, which works best with unsewn yard goods, is another possibility.

Premium on Efficient Fabric Use

Since lunar cotton still represents a 50% investment in "foreign" hydrogen and carbon, there will be strong incentive to use it efficiently. I am reminded of the yearly contest run by POPULAR SCIENCE for designs in plywood, for which the most important criterion is most efficient use of the whole sheet or half-sheet as the case may be. Patterns to be featured in books for the lunar home sewer will likewise take care to use the whole of the required yardage. This may mean "fuller" garments or accompanying accessories made of the same piece: ensembles. Any scraps can be used for doll-making, patch-work quilts, or oval-braided and other rag throw rugs. These latter items will also be the next stop for worn-out clothing items. Beyond that, if care has been taken in processing, will be full biological recycling.

Role of Early Settlement Enterprise

Instead of home-dying and home-sewing, yard goods stores will profitably include do-it-yourself dying and sewing areas with libraries of pattern and how-to books and hovering adepts. Because of the small size of the market, pre-dyed goods are likely to be available only in staple solid shades. Variety will be introduced by the end user or by entrepreneurs willing to produce limited runs of prints, etc., on speculation or on commission.

Pre-sewn finished items in common sizes and colors will be available as something to fall back on for those too busy or disinclined to fashion their own wardrobes. The penalty will be a somewhat uniform look. For everyday apparel, this may be tolerable for most. But for some some of the time, and a for few all of the time, personalizing embellishment of standard issue will be important.

Getting Fancy -- Adornments

The least expensive personalizations and perhaps the most versatile will employ all lunar materials: self-colored (metal oxide) fiberglass fabrics for appliques, shoulder wraps, and other add-on, wear-over items; medieval and cheerfully anachronistic chain-mail wear-overs for formal occasions; American Indian style glass-bead belts, pocket flaps, cuffs, collars, etc.; macrame shawls using glass and metal beads; metal and glass composite (non-brittle) sequins; buttons of colored and marbled glass, cast basalt, cut and drilled breccia rock, metal, dried and carved peach pits (a lost Chinese art); tassels of colored yarn, or even shorn human hair; etc., etc. You begin to see that settler resourcefulness will be much aided by a complete reference library to ethnic and folk methods of the pre-modern era. The effect will be a greater library of anything-goes than we are used to in modern society where our seemingly endless variety operates within subtle fashion dictates.

Inter-Settlement Trade & Specializations

Outlying settlements (road stations, specialized mines, etc.) may specialize in particular processes or fashions, developing them to a salable level. At any rate, Luna City will become the Paris of Space. For its wears will be the cheapest to import or copy for those living in Low-Earth-Orbit (LEO) or other Cislunar free space settlements.

Next to the Skin

Those not used to cotton underwear will have to forego silk and nylon, etc. If it is decided not to import elastic or Spandex banding, multi-snap boxer-style waistbands may be needed. Bras may be hard to come by, nylon hosiery as well. But there will be ample other means of accentuating and highlighting sexual differences.

Beyond Cotton?

Beyond cotton? Linen, better used for bedding, tablecloths and upholstery, is also a pure vegetable fiber and is cost-competitive with cotton. Rope making fibers fit the same class. If wool is to be introduced eventually, cavies (Peruvian Guinea Pigs) and goats are alternate sources. These may be introduced primarily for meat and dairy products and the availability may be restricted enough to add a market premium on such wool, over and above what is warranted by import-content.

A "pressure valve" lottery and other means of entry for imported exotic fabrics and special aparrel items

- A settlement-run lottery might award vouchers for rationed imported fabrics in lieu of cash prizes for a healthy outlet to the frustrations of usual choice restrictions.
- Incoming settlers fresh from Earth could wear borrowed costumes for the journey, that upon arrival would go to theater wardrobes and masquerade rental stores, it being bad taste to wear such terrestrial items except on very special occasions.

The Moon: an interesting place to live, don't you think? -- Peter Kokh

[in MMM #15, May 1988, NSS Chapters Coordinator Aleta Jackson sends her constructive comments. Look for "THREADS" reprinted below.]

OPENING THE SPACE FRONTIER: THE GOAL OF OUR SOCIETY

Commentary by Peter Kokh

Many People are *pro-space* in the sense that they want to see the country have a *strong* space program. That does not mean that they are for (or against) an *open space frontier.* This country could pull out all stops on a program of thorough robotic exploration of the solar system, even launch a Return to the Moon with a permanent *antarctic-style* Moon base, and join in an internationally crewed Mission to Mars. *None of this would open the frontier to you or me or our children!* The frontier could remain closed except to astronauts, scientists, payload specialists, technicians, and/or soldiers. *Examine your dreams!* Antarctica, to give the common ill-chosen example, is a closed frontier. That's not what excites us, gives depth to our dreams, moves us to action. *We,* you and I, we want a future that ˆWe can be a part of!

When the old L5 Society and the old National Space Institute agreed to merge, a declaration of purpose was signed by the presidents of both parent organizations which declared the goal of the new (National Space) Society to be the *Establishment of Human Settlements Beyond Earth -* not just garrison outposts mind you, be they military or scientific. Jim Muncy, who authored the text of this declaration, testifies in a recent letter that this "purpose" is openly scoffed at by many members of the NSS Board of Directors who call it "outlandish" *(precisely!)*

Since the merger, such respectables have done everything in their power to restrict the Society's function to that of a NASA Fan Club and Lobby. They are a comfortable part of the Washington Establishment and want to keep it that way. Symptomatically, most phone tree alerts have been aimed at prodding Congress to forgo oversight of NASA. This sort of action can be important, but unquestioning support of NASA is a mistake. As the representative of an increasingly risk-averse public, the Agency cannot take the risk that must be taken to open the frontier. It must inevitably neglect important research and projects. Recently, the conservatives on the NSS Board succeeded in blocking Society participation in just one such effort to do what NASA has been unable to do: build and launch an admittedly scaled-down Lunar Polar Orbiter to search for possible ices in permanently shaded regions of the Moon's polar area. Not our job, they say.

One Unique Chance to Change Course

The choice now before us is to ratify the name "National Space Society" [picked by Ben Bova in advance of the merger finalization in order to derail efforts to pick another name] or to replace it with "Space Frontier Society." All NSS members should now have received their ballots. This gives us a unique right now opportunity (ballots will be counted May 7th) to reassert our dedication to the *Big Dream* of mankind moving beyond cradle-Earth.

Yes, we are a radical group working to usher in a new era! Or we can settle for the *Little Dream†,* the respectable dream, the *easier-to-talk-about* dream, the *national consensus* dream. Changing our name would mean repaving the short inroads NSS has already made into the public consciousness. It would mean inconvenient explaining. It would mean phasing out lots of printed material with "NSS" on it. (Unwisely, new color brochures with the current name have just been printed by the ton in an effort to entrench the current name and sway our vote.)

The *right* choice, *wouldn't you know it,* is the hard choice, not the easy one. We have a chance, never to be offered again, to move beyond the timid projects of the current NSS Board and lay the symbolic foundation for bolder deeds. Without the lukewarm name, we may lose lukewarm members. *So! - Ad Astra! -* Peter Kokh 3/32/88

[The NSS membership voted 2:1 to keep the National Space Society name, indicating that we are to be about this nation's space policy and program, not about opening the space frontier.]

[NOTE: The above editorial would seem to be out of place in a collection of MMM Classics as it deals with a "dead issue." But in fact, *"the road not taken"* continues to loom before us. When we *change course* matters less than that we do change course. We won't begin to make real progress until we realize this, and make the paradigm change that still beckons in 2004 just as it did in 1988.

It is not a battle between "us and NASA" but between those of us who would settle for less, and those of us who realize that there can be no compromise achievement. *We settle space, or we do not.* For practical purposes we have taken the road that is acceptable to those many fellow travelers who share but part of the vision. But in the long run, this will turn out to be a false practicality because it cannot deliver.

We need to search our souls, those of us who would go all the way, and put priority on those means and choices that alone can deliver the dream. The cost will winnow out those who are not up to it, those content with lip service, those happy with wooden nickel "outposts" that have no chance of ever becoming settlements. PK 7/17/2004].

Colonist Energy Quiz

by Peter Kokh 3/88 - updated 3/04

QUESTIONS

1. Area for area, the Moon is hit by more meteorites of size (large enough, let's say to survive a traverse through Earth's atmosphere) than Earth. True or False?

2. The crater-forming bombardment of the Moon has occurred at a steady rate throughout its four and a half billion years of existence. True or False?

3. We do not yet know if there is uranium on the Moon. True or False?

4. Economic nuclear power for lunar settlements depends on the uncertain availability of lunar polar water-ice deposits for reactor coolant. True or False?

5. The Moon's surface averages the same distance from the Sun as Earth's, thus it receives the same intensity of sunlight. True or False?

6. Solar power plants on the Moon will require considerable import of terrestrial materials such as Gallium Arsenide to make photovoltaic cells for solar panels. True or False?

7. A solar power satellite located at the L1 Lagrange point 40,000 miles Earthward from the Moon would require no station-keeping fuel. True or False?:

8. The Moon has enough native ingredients for a superconducting cable to circle its equator, connecting intermittent solar power stations, thus able to supply ample power with no line loss to all points along the route, night and day alike. True or False?

ANSWERS

1. False. The Earth's deeper, wider-extending gravity well sucks up perhaps eight times the impacting bodies size for size, area for area, as the Moon. 70% of these fall into the ocean. Some fall on the Antarctic and Greenland ice. Evidence of the rest is soon erased by erosion and other geological processes not present on the Moon to erase or erode craters there.

2. False. Almost all of the bombardment that has created the Moon's familiar face occurred in the firs half-billion years, as the bulk of the solar system debris left-over after early planet formation was swept up by the new planets and their satellite moons. The lunar "seas" filled with lava sheets some 3.9 billion years ago. The rarity of craters on these basaltic plains, compared to the"saturation-bombed" highlands, gives us a good idea of the dramatic drop-off in frequency of impact that occurred before these maria-filling outflowings of magma.

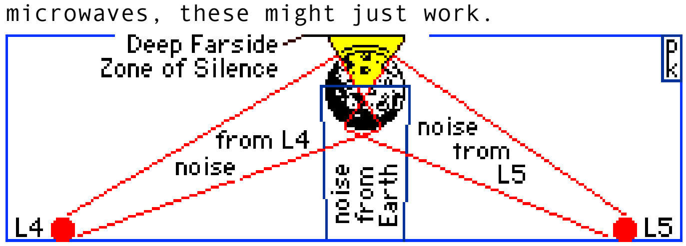
3. To produce the lava that upwelled to fill the large mare basins, the lunar interior must have thoroughly melted. As the Moon probably accreted "cold," the source of this heat must be radioactive elements, among them Uranium. Uranium usually accompanies Thorium, and we have direct evidence of the distribution of Thorium from orbital sensors aboard some of the later Apollo Command Modules.

4. False. There is another option. An alloy of 23% sodium and 67% potassium, both present in economic amounts in lunar regolith, is a eutectic liquid between room temperature and several hundreds of degrees Fahrenheit. Called NaK (say like knack) from its chemical symbols, this liquid has substantial thermal carrying capacity and could be the coolant of choice for all sorts of industrial applications. If we do find sufficient polar water-ice and are able to harvest it economically, we may be able to use it for this purpose, guarding against both freezing and boiling temperatures.

5. False. We are talking about *surfaces* here. Both Earth's atmosphere and the water vapor in it absorb some sunlight. And then there are clouds, always covering a substantial percentage of the Earth's surface. The lunar *surface* receives more than twice as much solar insolation in terms of watts per square meter as does Earth's. (Earth's average temperature is some 50 degrees Fahrenheit higher than the Moon's, paradoxically, because Earth loses heat much less rapidly than does the Moon, the oceans especially acting as enormous heat sinks and thermal flywheels.)

6. There is no law that requires building anything from the best possible materials or one that requires the highest possible efficiency. A study conducted by Space Studies Institute identified ways to build solar power stations with 99% lunar-sourced materials with only an 8% weight penalty. Especially if we are talking about solar arrays on the Moon's surface, the weight factor becomes irrelevant.

7. False. A better possibility would be SPS stations in stable L4 & L5 Lagrange points, co-orbiting Earth "in formation" with the Moon, respectively 60° ahead and behind the Moon in its orbit. These stations would cover 2/3rds of the Moon's surface, reaching 60° around each limb into farside. Once thought too distant (c. 240,000 miles, 384,000 km) for efficient power transmission, using laser beaming instead of microwaves, these might just work.



8. We can't yet answer that. Abundant aluminum becomes superconducting at far too low a temperature to be useful. Niobium/Tin, the best choice until quite recently, is too scarce on the Moon. Newly discovered "warmer" superconductors rely on oxygen (yes), yttrium (yes), barium (no), and copper (no). Just reported are composites including oxygen, strontium, calcium (all yes) and copper (no). But breakthrough research into high-temperature superconductors is still in its infancy. The stakes are high. If we find a superconductors that can be made entirely from elements abundant in the regolith and cooled by liquid oxygen, we will be in business. A Moon-girdling "dynequator" could render night and day irrelevant.

ELECTRIC OPTIONS

For Lunar Settlements: Five persons debate the issue

Edited by Peter Kokh

[MLRS member Louise Rachel favored the Solar Option for power generation for Lunar Settle-ments in her recent article in the January issue of *Moon Miners' REVIEW:* "What to tell your Irrational Environmentalist Friends about Developing the Moon" which brought forth two rebuttals in favor of the Nuclear Option, printed below, along with additional feedback.]

Jim Davidson, Pres. Houston Space Society

I thoroughly enjoyed Louise Rachel's article in the latest *Review.* Not only was it extremely well written, but it brought to mind several "encounters" with environmentalists whose anti-technology streak is wider than their shirt fronts.

Lunar nuclear power is not an option one wants to emphasize or even mention when discussing lunar development with most environmentalists (unless they come out and say "I think nuclear power is so much better than coal.") Still, I think some of Rachel's criticisms of the nuclear power option are not well-founded.

She notes that plutonium is heavy. More important, perhaps, uranium is heavy. Plutonium is a byproduct of fission reactors; it is not commonly used as a fuel. (Its most common application is in fission-fusion bombs, quite the environmental catastrophe.) Uranium may be available on the Moon, limiting the need for its importation,. One of the major gaps in our database is a complete mineral survey of the Moon. We do have extensive samples from six sites (and a few samples from Soviet probes,) but lack general knowledge of materials availability Luna-wide. A lunar polar orbiter could begin to remedy this situation.

[*Lunar Prospector, in whose origins both Jim Davidson and the MMM editor played key roles, found substantial Thorium deposits from which fissionable U-233 can be made in a Fast Breeder Reactor.]

Indeed, if we get to the Moon, set up our reactor and find there are no fissionables but the ones we've brought along, we'll have to begin addressing alternative power options immediately for implementation in thirty years when our [original] nuke goes our or sooner, when we outgrow its capacity. If we do find natural uranium, we'll need a significant power source to purify it. Also,purification of natural uranium to power-grade uranium may require non-native materials. Again, at this time, without knowing what's generally or even minutely available, we can't say.

Problems encountered on Earth in keeping nukes online and operating safely are not universal. France and Japan do extremely well in these regards because they each use mass-produced nukes based on one or two designs for each country. U.S. difficulties with operator error often result from the uniqueness of virtually every U.S. nuke. Also, few U.S. contractors have built more than one plant of the same design -- leading to "built-in" but not necessarily inherent problems throughout the domestic nuclear power plant industry. The Soviet Chernobyl accident resulted from operator error during extensive experiments with a type of nuke (graphite cooled) that has been abandoned in the West since about 1958 when the United Kingdom had a much less sever, though equally worrisome accident with a similar design. Modern reactors with adequate cooling systems, redundant cooling systems, and containment buildings have obviated the severity of the Chernobyl event.

So-called "pocket-nukes" are being developed at Sandia Laboratories, They address many of the difficulties we've encountered with large scale nukes. Pocket nukes are thermal electric generators, about the size of an old VW microbus. They use thermal power or radioactive decay to generate electricity. Their chief advantages:

(1) limited maintenance -- few moving parts

(2) few operator actions or operator errors

(3) modularity and portability -- just plug in a few more to expand the power supply

(4) factory assembly & sealing -- production line economies of scale will make pocket nukes cost competitive with small diesel power plants on Earth, and almost certainly a superior economic choice for lunar nighttime operations, and

(5) total containment -- use for thirty years and then store as a unit without ever exposing the radioactive core.

Waste disposal is a problem with many acceptable solutions. Vitrification is the process of combining spent nuclear fuel with silicon dioxide (i.e. sand, in adequate supply on the Moon) to create a glassy substance. Vitrified waste is a *"hot"* ceramic, it does not corrode steel. Then again, on the Moon, very little will. Water and water solutions are the major corrosive villains on Earth -- thus storing nuclear wastes in a salt dome or near an aquifer on Earth are asking for trouble. Water and salt domes, are not, and may be expected not to be, readily available on the Moon. Thus stabilized vitreous wastes stored in well-marked craters on the Moon, should pose no problems. Waste disposal is more suited to the lunar environment [with no atmosphere to speak of, nor any ground water] than to the Earthly environment.

Now we come to the meteorite question. First, meteorite strikes on a given target area the size of a nuclear power plant are common; but strikes of a size to do much damage are rare. Let us postulate such a meteorite, though, and evaluate its potential impact (pun intended.) Let's look at two cases: strikes on a pocket nuke cluster or a large-scale nuke, and strike on a waste depository.

In the case of a pocket nuke cluster or large nuke, we'll assume these are buried two to four kilometers from the nearest habitation. They are buried for the radiation protection of the maintenance personnel, to provide insulation (no sense radiating heat into space when you can sink it into solid rock for power cogeneration,) and as protection against micro-, mini-, and minor meteorites. [If there is a nearby lavatube, placement within it would render this whole discussion moot. - Ed.]

Now along comes a major impactor and knocks a hole in one or more pocket nukes. The impact crater is a few meters in diameter, the ejecta travel about 100 meters, and you've got a clean-up problem -- but it is entirely contained [probably in the host crater where the nuke has been situated.] There is no "fall-out beyond the ejecta curtain because there is no atmosphere to suspend particles and no wind to carry them anywhere.

Postulating ever larger meteorites on the impact site does create ever larger problems. Eventually, you get an impact large enough to open the containment building of a large-scale nuke. But a meteorite large enough or fast enough to put radioactive ejecta into populated area two kilometers away is going to create ground shocks sufficient to depressurize tunnels, topple structures, and create a significant problem with or without landing on a nuke.

Two point to note. First, such meteorite impacts are rare. The odds of a given person being struck by lightning in his/her lifetime on Earth are greater than the odds of such a large meteorite impact occurring at a given spot over an eighty-five year period on the Moon. That you so so many craters from such impacts all over the Moon does not tell you that it happens frequently, but that lunar erosion is very slow.

Second point, radiation suits will be basic apparel for all the style-conscious Moon folk whether there are nukes on the Moon or not. Your pressure suite is rad-hardened due to the danger of incident solar [flare] radiation [and incessant cosmic rays.] An unhardened suit would offer some protection, but the Selenian who wears it for several days will rapidly accumulate a fatal dose. Sunburn takes on a whole new meaning. So we have a disaster which includes radioactive ejecta from a major impact. Cleanup is straightforward. Selenians in radiation/pressure suits use Geiger counters and bulldozers to move the radioactive ejecta to the waste processing plant where it is vitrified and clad in steel for shipment to the waste repository.

Finally, we come to the strike on the waste site. it is in a crater at least fifty kilometers from populated area. Let's specify that the crater must be at least one kilometer across. Dozens of stacks of cubic, steel-clad, vitreous nuclear waste containers from, say, fifty years of using nukes on the Moon, are scattered within the crater. Each stack is partly fortified by regolith which has been pushed up on each side [think landfill.] Now a meteorite strikes. The crater wall serves to contain most, if not all ejecta. Whatever ejecta does escape is easily handled. A Geiger counter will reveal some glassy pieces to be moderately "hot" compared to the "extremely warm" background radiation. These materials can be bulldozed into new containers and placed back in the crater. Again the workers are suitably protected by their suits.

The waste depository is well marked and distant from population to avoid inadvertent exposure to slightly higher radiation dosage. It is contained in a crater to limit access and greatly decrease the range of the ejecta curtain. Fallout is limited to the range of that ejecta splashout, and if it reaches 50 kilometers, your colony is almost certainly gone anyway from the [seismic] violence of the impact alone. [placement in a more distant lavatube would remove all these issues. - Ed.]

Now, having said all this, I would like to add that I would prefer a cleaner, safer central power source for night operations other than the nuke. When one is invented or offered, I will embrace it wholeheartedly. Perhaps fusion power will have fewer problems. Certainly we know that Helium 3 is available on the Moon and may be useful in future fusion power systems.

Indeed, a good solar battery would be everything Rachel says it is, a boon indeed. Nevertheless, if we must use nukes, simple care and planning should make them relatively innocuous. And if nothing else works, the two-week nights can be an opportunity for some extra Z's.

Robin Miller, President of Peoria L5

Rachel says that the use of nuclear power on the Moon is "questionable." and asks "how far must the reactor be from the [lunar] colony to make sure that the colony is safe if the reactor gets hit by a meteorite?" This is a straw-man argument ... which falls apart readily under analysis. Let's discuss the practical implications of such an event. There is no atmosphere [significant to this discussion] on the Moon. How will radioactive material (presumably what makes this a safety issue) be transferred to the colony? Will not all the colonists have pressure suits to protect them from the vacuum and radiation of the lunar environment?: How "safe" will the (now power-less) colonists be when the 14-day night falls on Luna? At that point, I don't think the colonists are going to give a damn about hot isotopes.

Further, there is nothing inherent about nuclear power plants that make them meteorite magnets; the colony is far likelier to be hit than the reactor, due to its larger surface area ... I don't like commercial nuclear power on Earth, because of the potential for radioactive releases into our living biosphere (due to bad designs frozen in place: we *can* do better);

but, like it or not, nuclear power is an "appropriate technology" in deep space or on worlds without biospheres, like Luna. ("Appropriate" from an 'environmental/technical standpoint -- political issues like what happens if an uppity lunar colony gets its supply or fissionables cut off by the sponsoring governments on Earth, will not be considered at length here.)

This does not mean I endorse messy power piles scattered over the lunar landscape. If it's messy, there are losses; and, as noted, deliberate losses are *dumb.* Doing dumb things in a hostile, unforgiving environment tends to be lethal, and therefore self-correcting. Last-heard phrase in space: "I won't make *that* mistake again ..."

Louise Rachel, Milwaukee LRS, Replies:

Robin Miller and James Davidson have written supporting nuclear power for lunar colonies, something about which I have expressed skepticism. I'd like to reply.

Regarding safety, *on reflection, I do* accept some of their arguments. I'll grant that th nuke plants will be buried a safe distance from the colonies themselves; that without atmosphere, there would be no [air-born] fall-out even from a major accident; that radiation-hardened pressure suits would be standard protective equipment for all in any case; that large enough meteor strikes to do serious damage really aren't that common. In short, I'll accept that nuclear power plants on Luna will be a whole lot safer than similar plants on Earth. The question that remains is "is that safe enough?" My answer, "I'm still not sure."

Both my correspondents suggest that designs could be a lot safer than most current U.S. installations, and this too I'd agree with. But still, even with the improvements Davidson mentions, nuclear power plants will never be a simple technology., There will always be any number of things that can go wrong, and as we all know, *anything* that can go wrong, will, sooner or later, but probably at the worst possible time. And nuke plant problems can be catastrophic when they happen at all. As Miller pointed out, any accident that cuts off power to the colony will be extremely serious, with the loss of power being far more dangerous than possible nuclear contamination. One response to that fact would be to have a good backup power system present from Day One. But wouldn't it also be sensible to use the absolutely *most reliable* power technology available as the main source?" I'm not just that convinced that nuclear power qualifies on that count.

My problems with lunar nuclear waste disposal are perhaps partly aesthetic. Davidson has me convinced that in the lunar environment the stuff could probably be stored safely. But I just don't like the idea of even a small contained area being rendered uninhabitably hot for half of forever. This is not the way to walk lightly on a new world; it's not optimal stewardshsip. And good stewardship is important, I think -- even on an airless world.

Finally, Davidson hopes that uranium (not plutonium, as I said -- my slip) might be found on the Moon, thus obviating costs of importing the stuff. I'd respond that we still don't know for sure that it's there, or if so, where; and even if it is found, there would sill be costs of mining and transportation as well as refining. The cumulative costs would still be great even if we could count on lunar fissionables, and at present we can't. I think it makes more sense to base plans on what we know rather than on what we hope, and in this too, nuclear power doesn't look wonderful to me.

Note that I'm not saying "No Way!" to nuclear power plants, but rather asking questions about them. If they turn out to be necessary after all at the beginning of lunar colonization, that fact absolutely won't interfere for an instant with my accepting an invitation to join the colony. but for the cost, reliability, and yes, aesthetic reasons, I'd like to see us look at developing solar and battery-based [or fuel cell-based] alternatives as soon possible.

Gregg E. Maryniak, Executive Vice President of Space Studies Institute:

I noticed in the *Moon Miners' Manifesto* that you are arguing on the side of solar energy on the Moon. While I have nothing against nuclear power per se, even discounting for the obvious environmental clamor, it seems to me to make sense to take the long view and to use, wherever possible, indigenous resources. I think there is great value in doing this early on as a matter of principle, and for more pragmatic reasons, aswell (such as potential for replication.)

The purpose of my note is not to preach to the choir, but rather to enclose some data from our recent Lunar Systems Study n using solar power for oxygen production *and for storage of energy during the night cycle via hydorogen-oxygen fuel cells.* [italics added by the editor. See "Powerco" in MMM #7, where we put forth the same idea.] This material comes out of our recent Lunar Systems Workshop, about which a paper is in production at this time. The principal elements of the system we came up with are these:

- In the daytime, the Sun's energy is collected by the solar arrays and this electricity is used to break water down into hydrogen and oxygen
- In a fuel cell hydrogen and oxygen are combined to form water and produce electricity during the lunar night
- A "three-drum slusher" is used to cover a tank cluster with lunar soil.
- A large radi-ator and sunshade.

The "Ground Rule" guiding the design is to store enough power (electrolyzed water) to run the production facility for liquid oxygen at at least 50% rating during thee lunar night, avoiding shutdown. The plan calls for a target production rate of 250 tons of LO2 (liquid oxygen) per year and requires 1 megawatt of power daytime, 500 kilowatts nighttime and would recycle 45 tons of water in the electrolysis-fuel cell cycle of which 40 tons, the oxygen involved, is lunar derived. While the solar collectors (40 tons), power module (10 tons), and storage tanks (45 tons) would originally be brought from Earth, eventually such items could be largely lunar-sourced and manufactured. In the SSI plan, this installation would precede delivery of a full lunar base with mass driver. [end]

Peter Kokh, MLRS, Manifesto Editor:

I have several points to make, *briefly.*

• If we did use nukes, it might be good not to just bury them, but to site them in underground lava tubes if any are handy to the chosen colony site. Ditto with waste disposal areas. There, they might be safe except from impacts expected every several tens of millions of years. Coolant could transfer generator heat to surface installations.

• See Colonist Energy Quiz, above, questions 3 and 4 about the probability of lunar-source uranium and reactor coolant

• Seeing that there is no ground water to worry about, nukes could be positioned over deep shafts and simply dropped in case of meltdown or end of useful lifetime with a plug of regolith or lunacrete added on top.

• On the other had, nighttime solar batteries *are* available. I suggested one such possibility in the article "Powerco" in the July '87 MMM #7 i.e. using excess daytime solar power to electolyze some of the water reserves into hydrogen and oxygen to be recombined in fuel-cell banks during the nighttime to generate power. In addition, fresh shipments of hydrogen from Earth []or scavenged from solar wind-derived volatiles in the regolith] could be saved for nighttime "burning" in such fuel cells with freshly mined lunar oxygen. (It is humbling that both Jim Davidson and Robin Miller who must have read this article were so unimpressed by it as to assert that the nuclear solution was the only one available.)

• To my rescue, SSI Executive Vice President, Gregg E. Maryniak, in aphone conversation with me has stated that the hydro-soolar fuel-cell system is the current consensus solution to nighttime lunar powr genration. Westinghouse hopes to have a 7.5 megawatt fuel cell system in operation later this year for peak-load assistance.

• Nonetheless, (call me a cynic) it would be perfectly in character for NASA to "decide" that the original Moonbase must depend on an Earth-built pocket nuke. But the bottom line, I think, is "*which technology the growing settlement can first and most economically provide from its own infant technology base*" (not a consideration for planners of a Moonbase for whom growth, much less expansion into settlement, is not foreseen.) Both systems have sophisticated elements, that is if they are designed for maximum efficiency (which should probably *not* be prioritized, as not replica table by settlement industry.)

• Personally, my approach, being not that of the absentee engineer (on Earth) but that of a potential colonist who would be living with the system, I still prefer solar because I like the idea of following the Moon's natural rhythms. There are no seasons on the Moon. On the other hand, lunar monthly rhythm is strong, much stronger than the weak mensal effects on Earth. To purposely suppress such monthly rhythm with brute nuclear-all-you-want-at-any-time-power is to toss away one of the few naturalizing props lunar living can provide. If it means, as I said in the "Powerco" article, that labor-intensive activities be concentrated in the lunar sun-down period and energy-intensive activities dispatched preferentially during the sun-up period, I think that would provide a very psychologically healthy inhale-exhale cycle. The month, or "sunth" as I call it, will provide much of the special character we might expect lunar "culture" to acquire.

• On the practical side, it is possible to move well beyond the low efficiencies of the SSI-designed system. Conventional electrolysis can be improved on by other methods of water splitting. I refer the interested reader to pp. 55-79 of "The Forever Fuel: the Story of Hydrogen" by Peter Hoffman (West View Press, 1987) Traditional electrolysis runs at 70-72% efficiency. A new solid polymer electrolyte (SPE) method developed by GE has possible efficiencies of 85-95%. Of course, replicatability on the Moon from local resources remains the primary consideration. A promising new alter-native is thermochemical water splitting based on Moon-available sulfur as a catalyst. Perhaps the most promising research line is GE's high temperature steam electrolysis (HTSE) operating high temperature fuel-cells in reverse, "the main advantage being that with increasing temperatures, the requirement for electrical energy [input] is drastically reduced" [improving efficiency.] [p. 68, op.cit.] called HOT ELLY (High Operating Temperature ELectroLYsis)

• *The Development of a Lunar-Appropriate Hydro-Solar Cycle Technology is Possible Now!*

P.S. from Robin J. Miller

I'd like to clarify for MMM readers, my views. I have no particular preference for nuclear power on Luna, but I do have a preference for basing decisions on correct assumptions. *This* is what I was going after in my critique - objecting to some of the assumptions about nuclear power that were used as arguments against its use. Certainly any lunar colonists are entitled to having the best thought-out system for their electric power needs; but discarding the nuclear power option for the wrong reasons would be doing them a disservice.

There are better arguments against the use of nuclear power; and I alluded to one in the segment of my remarks above, i.e. political considerations. Other negatives include positioning supplies of fissionables atop Earth's gravity well [... potential orbiting nuclear weapons, prohibited by treaty?] self-sufficiency issues -- colonial powers would probably urge the colonists to go nuclear if resupply, and control were Earth-based. Potential colonists should be vigilant against these tacit control mechanisms. <RJM>

Without Strategic New Projects, Space Activism Must Fail

Commentary by Peter Kokh

Since the dawn of space activism in this country with such pioneering groups as the L5 Society and the Space Studies Institute, enthusiasts impatient with the pervasive apathy of the public, the media, the Congress and the bureaucracy, have brainstormed for ways to make inroads into this mass indifference and build a groundswell of support for our vision of how things could be. The going has been rough.

Behind this approach lie two fallacious assumptions which stand or fall together, and which have insinuated their lethargy-producing toxins into the thought habits of too many of us.

- The first is that only the government -- through NASA and its client contractors -- can put into place *each and every element* needed to establish an open space frontier.
- The second is that Society members, you and I, are only good for letter writing, phone calls, and gadfly work in general (and, of course, money) and as yet more ciphers in a ballooning signature-list of supporters and petition-signers to wave in the faces of stubborn politicians with other priorities.

The paralyzing tentacles of such inappropriate thinking and silent dogma must be cast off both by the grass roots membership of space enthusiast societies and by their leaders. For limiting our project track to browbeating Congress and increasing public awareness and support, as important as these things may be, are by themselves and without supplement, hopeless measures that will not win the prize we seek.

if we hope to break out of the all too comfortable rut of low Earth orbit activities (Tucson's Jack Kirwan insightfully calls this "yo-yo space.") we must first radically alter the present way of doing business. Business as usual means letting "George" i.e. NASA do all the R&D and then ballyhooing the eventual spin-off afterthought technologies. Teflon hoopla, with no apology to its fans, is good for one thing only, neutralizing opposition; it will never win true converts.

Meanwhile the spin-off regime leads Earth's economy into ever greater parasitic dependence upon space technology, with the corollary that *space becomes a far more expensive proposition than it has to be,* because the costs of R&D get charged to the space budget and not to the spin-off using consumer.

Concrete feasibility demonstrations

We must seize the opportunity to demonstrate to the public *the concrete feasibility* of the long range goal we ourselves instinctively believe in: self-supporting settlements beyond Earth that rely on non-terrestrial resources. This means *pre-developing the technologies that will be needed to move beyond the initial Earth-dependent footholds established on the Moon or elsewhere.* We can do this profitably, here and now, by ferreting out Earth markets for such technologies, thus billing the consumer for "spin-up" -- loading the shelves in the process with the technologies we anticipate needing -- instead of billing the Space Budget for "spin-off." NASA itself offers us the opportunity, for -- its faith being less far-reaching than ours -- it confines itself to R&D of hardware and systems needed for short and intermediate range goals.

The movers and shakers in the Society, by looking at membership with glasses that filter out all but the peon in us, seriously underestimate the vast resources of our collective talent pool. We can, amazingly, do more than read, write (letters and checks), and dial. We are, I'll wager, an above average reservoir of diverse talents and abilities that can be put to work. To be sure, some of us cherish our role as passive consumers of space news ("space news potatoes") and nobody, thank you, is going to light a bomb under our ever-widening butts. But others of us itch for ways to become involved beyond those afforded by traditional chapter-type activities for which we may not be temperamentally inclined. When the Society invites us to join with the promise that we will become part of a team and then only offers us a magazine to read, it is clearly not delivering. Some wonder why *members* fail to renew. The truth is *subscribers* fail to renew because we have failed to give them *the membership that only comes with participation,* except in the unimaginatively restricted form of chapter activity. This can be remedied.

Sketching a Second Chapter Project Track

1. The Society should officially sponsor any member-provided news vehicle (print or electronic) for the exchange of insights between members and others, national or international, on the potential terrestrial market for various technologies yet to be developed that anticipate those that future pioneers will need to snip away at stubborn umbilical import ties to Earth. Such a *society-wide* insight-exchange-vehicle does not yet exist.

2. When such promising market niches here below have been identified, the Society should aggressively promote their exploitation by aiding in the creation of a wholly separate venture fund to assist would-be entrepreneurs who have done their homework, in carrying out demonstration projects. Such a fund can be fed by special subscription of supporting members and others, by appeals to space supporters who happen to be planning their estates, and in yet other creative ways. Once a new technology application has been demonstrated, these entrepreneurs would be encouraged to seek out traditional sources of venture capital for the means

to begin actual production. Contingent upon market success, the original loans from the Society-sponsored venture fund would be repaid. The resulting product lines would be advertised as “anticipating lunar technology needs,” thus gradually replacing widespread public disbelief with a perception of reasonableness and desirability. And something we urgently need!

3. On a seemingly less ambitious but wholly complementary tack, the Society should encourage industrious and inventive members to find lunar-sourceable substitutions - item by item - for the myriad of industrial, commercial, and domestic products settlers will want that are now commonly (if not only) made from organic materials such as plastics, wood, paper, fabrics, and synthetics. For it it is to survive, the settlement must seek to reserve as much as possible of its allotment of imported or otherwise hard-won hydrogen, carbon, and nitrogen for its growing biosphere.

4. This new “let’s-roll-up-our-sleeves” Project Track will not bleed the Society’s admittedly too small budget. The contrary is true. Not only will each endeavors attract enough funds to be self-supporting, but our membership ranks will swell (and stay) as the perception grows that we are not (any more) “all talk, no action.” - PK

RURAL LUNA

LIVING IN THE “BOONDOCKS” CAN BE RELATIVE!

By Peter Kokh

If the Moon, all 14.5 million square miles of it, is not "rural", what is? To be sure, the first beachhead bases will be preoccupied with doing Lunar Science and successful demonstration and pilot plants for the production of Liquid Oxygen from the fine lunar soil. Such footholds will hardly amount to small "hamlets".

But upon first expansion, the Moon bases will concentrate on feasibility demonstrations of various forms of lunar-sourced construction; they will then proceed to the manufacture of a spectrum of building products for use locally, in Earth orbit, and in Mars orbit. Leveraging on these beginnings, if we make a serious effort to fully diversify on-Luna manufacturing to exploit the LEO and Mars markets, then one or more genuinely urban biospheres will arise.

So back to the question: given this incipient "urbanization" of one or more lunar sites, will there be any room on the Moon for homesteaders who prefer more elbow room and looser ties to civilization?

Well beyond the outskirts of "The City" (until there is more than one, locals may not pay much attention to proposed proper names), there may be a growing number of mobile nomadic science / prospecting camps searching for economically abundant concentrations and deposits of useful elements that exist only in taunting traces in the soils around The City. If such lodes are found, new settlements may be founded to mine and ship them to urban factories or to render them into marketable products on the spot. Depending on the market for such products, the new site may remain a rural village or grow to become a rival city. Bear in mind that rich concentrations of specific ores are not to be expected on the Moon except in a few Sudbury-like astroblemes, relics of the impact of particularly mineral-rich asteroids. On Earth, most ore deposits have been laid down in multi-million year long episodes of hydrotectonic leaching, a process probably unique to Earth and Io in our Solar System. But there are different soil types: highland soils, and a variety of mare soils deposited by successive episodes of lava flooding. Further, some crater central mountain peaks may be upthrust mantle material such as relatively denser pyroxene. The prizes will be useful concentrations of copper, platinum, lead, etc., all of which are unlikely.

Both underneath sites well known for the reddish glows of TLP ("transient Lunar phenomena") and elsewhere (where there are no 'leaks') there may lie deep underground pockets of unreleased volcanic gases or volatiles. No matter what their composition, detection of these reservoirs will likely lead to new homestead locations. Particularly harvestable water ice and / or carbon dioxide ice deposits (when mixed they are called 'clathrate') will call for at least temporary encampments as well.

Thus a number of lesser towns or even rival cities may develop, all feeding the local lunar economy, which in turn supports ventures in LEO (Low Earth Orbit) and in the Mars PhD area, and sooner or later in the L4 / L5 locations. Roads will be built apace, and along them, at intervals, will be needed way stations that support road maintenance, refueling, vehicle repair, closed life support system recharging, flare shelter, inn-space, food, first aid, communications, etc., and probably serving not only travelers and truckers along the main routes, but off-road excursions for tourists, prospectors, and scientists.

Where the beaten path takes a long detour about some obstacle such as mid-mare wrinkle ridges, rilles (ravines that have resulted from collapsed lava tubes), or sand scarps, for example, is it not plausible that entrepreneurs might build bridges, fjords, or cuts and rightfully establish tolls for the shortcut they provide? Here and there, the run-of-the-mill lunar scenery ("once you've seen one crater, you've seen them all" is far from the truth) is relieved by some excep-tional vista e.g. the Alpine Valley, the crater rims of such unique beauties as Aristarchus, Copernicus, Theophilus, and Tycho come to mind; such spots may support tourist inns. A site along the east or west limb (90° east or west) will afford monthly Earthrise and Earth-set (caused by libration resulting from the Moon's eccentric orbit about Earth). The Earth will rise a few degrees clear of the horizon and a fortnight later be a few degrees below it, affording "twin skies": half the time a picture-window postcard scene of the Earth-kissed horizon, half the time (with Earth out of sight) the Milky Way will fill the sky with a brilliance we can only imagine. Here, especially along preexisting roads, would be a good spot for a honeymoon motel or a get-away-from-it-all retreat house, etc.

But not to wax too romantic, there will be dampening facts of lunar life. Firstly, to insure that there is a sufficient economic basis for such rural locations, a lunar authority would do well to license them, restricting them to minimum intervals depending upon current traffic volume projections. Survival without traffic support will be far, far more difficult than it is on live-off-the-land-friendly Cradle Earth! Applicants or applicant groups for rural openings may well have to bid for them, based on skills, abilities, talents, financial resources, and experience. At first the niches for such rustic rooting will be few, but they should grow exponentially as the multi-site economy expands and diversifies.

Secondly, hermitages and single family mines, farms, or inns, etc. may be both unsafe, and unendurable. The reason is that unlike on Earth, where we all share the same biosphere, on the Moon, each city, town, village, hamlet, camp, and isolated homestead must be a biosphere unto itself. And the smaller the biosphere, the less stable, less diversified, and less satisfying the sustenance it affords. Unless you and yours are stoics content to live on chlorella and algae mush, there will be a certain minimal size to any such isolated biospheres. To support a bare minimum exchange of service functions and division of labor as well as menu variety and social outlets, the village-sized, or at least hamlet-sized, island of humanity will likely be the smallest the Moon could support. As in lunar towns and cities, individual residences, greenhouses, workplaces, etc. will all be interconnected by pressurized passageways to afford the convenience and safety of integrated biospheres.

And you thought the Moon would be the ultimate get-away-from-it-all! Best head for some of the less settled areas of good old Cradle Earth! Our challenging gray neighbor may have room enough for small towns and villages, but the antisocial need not apply.

Such rural settlement as does occur will undoubtedly provide opportunity for diversification of food crops, meat animals, ornamental plants, and specialized arts and crafts. Separation combined with ingenuity and diverse mineral endowments will suggest unique feature products for which the town or hamlet may someday be renowned. Certainly, a rural subculture will arise. Radio, folk song and dance, and country ballads, as well as its own special etiquette, brand of hospitality, and `ways' will instantly distinguish lunar rustics from city people. But they will share the Moon, a common bond which will set them uniformly apart from Earthsiders. The future of both urban and rural Luna will rise or fall together.

For the city dwellers, the existence of a number of rural communities will be both a safety valve and a constant source of cultural cross-fertilization and enrichment, as all Lunar citizens seek to continue their acculturation and adjustment to their new host world. The adventure should not be boring. -- Peter Kokh April 1988

THREADS

More on Made-on-Luna Frontier Apparel

(see “Apparel” in MMM #13 [above]

by Aleta Jackson, NSS Chapters Administrator

I am a long-time SCAer: Society for Creative Anachronism.[1] Part of the joy of being anachronist is researching period clothing. I have learned to card, spin, dye and weave my own cloth. I have studied the fabrics and dyes used in various cultures and continents. If you can get a bunch of SCA people together with your chapter for a weekend brainstorm about Lunar clothes, you will probably come up with some really dynamite ideas.

i think you’re wrong about silk; silk last a long time, masses very little, and has many applications, even after it’s starting to rot, which won’t happen unless you severely mistreat it. It won’t evaporate like polyester, it’s strong and elastic even under extreme temperatures, and is able to tolerate tremendous punishment. I bet someone could make a bundle of money importing silk clothing, and eventually a silkworm farm might be a great industry in one part of the colony. [2] mulberries (the leaves form the diet for silkworms) make tasty pies, too.

And don’t forget ramie, a vegetable fiber. Combined with rayon (which was developed to replace silk during WWW II and which I love almost as much a silk) it makes a lovely fabric. Ramie combined with linen (from flax), cotton and silk produces fabrics that take dyes very well. It also helps “wick” sweat from the body into the fabric and so promotes evaporative cooling.

Another vegetable fiber that combines well with cotton is agave. I bet you can find all kinds of uses for agave, which thrives in desert conditions. I have an agave bedspread that has been through the wars and is as soft and supple and lovely as new. I grew up in Arizona, where we grow both agave and cotton. Cotton takes a *bunch* of water. Agave is a water conserver, produces a good beverage, flowers, and fiber.

You can get some really *neat* dyes -- deep, rich, long-lasting colors -- from minerals mixed with everyday biodegradable chemicals such as urine, which is useful for all sorts of things. [3] I no longer have my wonderful dyeing books or I'd be able to write the formulae here, but check your local spinning guild [or the arts and crafts section in your local library]; I bet they'd be really interested in lunar clothing possibilities and they might have good suggestions.

Drawstrings have worked nicely for centuries, and I still make a lot of my pants with them. Skirts, too. Comfortable bras can be made by combining drawstrings and cleverly woven cloth which has been cut to give in the same "give"of elastic. Sometimes better and longer-lasting that elastic, it's what was donein the old days.

Unless, they're redesigned, what you will probably have to give up is zippers and return to laces and gussets, which aren't made from valuable metal or easily degraded plastic.

About bleach. Dilute lemon juice and sunlight work wonders. That's how I bleach my find handwoven linen Rumanian blouses and dresses. Which brings up a question you may have answered but I've missed: whatcha gonna do for soap? [4]

Sincerely,
Aleta Jackson

Editor's notes:

[1] The SCA adds much color to Science Fiction Conventions.

[2] Silk requires extremely labor-intensive unraveling of zillions of silkworm cocoons. If machines can be invented to do this task well, we may have an enterprise proposition.

[3] A Junior exhibit in our recent SW Wisconsin High School Science Fair showed good cotton-dyeing abilities for coffee, tea, onion skins and beats; and poor results with spinach and carrots.

[4] ? We'll have to look into that one.

Moon Miners' Manifesto – # 16, June, 1988

Frontiers Have Rough Edges

Commentary by Peter Kokh

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 technological 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 Philadelphia, Boston, 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

THE MOON IN HISTORY QUIZ

QUESTIONS

1. What evidence was there for early man that the Moon was spherical and not just a round disk?

2. How long ago was it first realized that the Moon was world-sized and that the Earth was not alone in this respect?

3. For how long have people been writing science-fiction stories about trips to the Moon?

3. When was it first realized that the lunar environment was probably airless?

5. How long after a realistic picture of the Moon became common, did the first modern science-fiction work appear about visiting the Moon?

6. When did something manmade first reach the Moon? *This is a trick question.*

ANSWERS

1. If the Moon were a flat disk lying all in one plane, the Sun would either shine on all of it, being this side of that plane, or on none of it, being on the other side of the plane. As it is, the terminator or line between day and night creeps slowly across the Moon, at a varying pace, giving us the familiar phases. This can only be if, the side facing us at least, is spherical.

2.In 130 BCE [before common era], about 2120 years ago, the Greek Hipparchus of Nicaea (SE of Byzantium, now Istanbul) demonstrated that the Moon was 30 Earth-diameters distant. Earlier, in 240 BCE, Eratosthenes had deduced from the Sun's lower noontime elevation in the sky in Athens as compared to Egypt at the same time of year, that Earth's diameter was of the order of 8,000 miles [the true figure is 7,926 mi.] Hipparchus thus concluded that the Moon was about 240,000 miles distant [actually 238,857 on average] and then figuring in the Moon's apparent angular diameter in the sky of 1/2 degree, used Greek trigonometry to arrive at a lunar diameter of 2,000 miles [actually 2,160.] Prior to this, there exists one reference to a belief that the Moon *must* be larger than the Peleponesus, the southern peninsula of Greece, about 130 miles across. But perhaps most people, then as now, never thought of the question, or cared.

3. The first known such story is by Lucian of Samasota who in his "True History" (2nd Century CE) wrote of a hero who sails into the Atlantic and is carried to the Moon on a waterspout. He spoke of the Moon, the Sun, and Venus as inhabited worlds. Along with most ancients, he took it for granted that air pervaded all space and therefore travel between worlds would pose no special problem of discomfort or inconvenience.

4. In 1643 CE Evangelista Torricelli first measured the pressure of air and realized that the atmosphere had to be confined to within a few miles of the Earth's surface. In 1687, Newton's *Principia Mathematica* explained that our blanket of life-sustaining air is held to Earth by gravity. The Moon's smaller size and expected lower gravity would not be able to maintain such an asset for long and it would be airless and waterless. The Moon's rough mountainous and crater-pocked surface had been revealed a bit earlier with Galileo's invention of the telescope in 1609. So by the 17th Century, a rather modern understanding of the Moon's nature had emerged.

5. Not until two centuries later when Jules Verne published his "From Earth to the Moon," still a classic, in 1865. He even had the necessary escape velocity from Earth figured quite accurately.

6. In 1949, when we first succeeded in bouncing a radar beam off the Moon and successfully recorded the echo. This was our first baby step in the long saga of trying to touch the stars, and the first hint that the Space Age would soon be upon us.

GLASS GLASS COMPOSITES

by Peter Kokh

Glass-glass-composites, more exactly glass-fiber / glass-matrix / composites, or simply GGC, are a promising new horizon for construction and manufacture. This new bird in the flock of materials available to man is still inside the eggshell but pecking away at it. What we know of GGC's promise we owe to Dr. Brandt Goldsworthy of Goldsworthy Labs in San Francisco, who at the request of Space Studies Institute in Princeton (SSI) made laboratory-sized samples and investigated their properties (his report is available for 3$ from Space Studies Institute \ PO Box 82 \ Princeton NJ 08540). His work gives reason to believe that GGC building materials will be as strong as steel or stronger, and considerably less costly in energy terms to manufacture.

The occasion for this bit of incubation of a theoretical hunch lies in careful analysis by SSI of the possibilities of producing serviceable metal alloys from the common ingredients in lunar soil. While the Moon is rich in iron -- some of it free uncombined fines -- and other important metallic elements such as aluminum, titanium, magnesium, and manganese, these are just starting points; to make alloys with good working properties, other ingredients in lesser amounts must be added. It turns out that our customary and familiar stable of alloys used on Earth often require recipe ingredients that are not easily or economically isolated from the soil. Furthermore, alloy production takes a great deal of energy and therefore represents a technology direction for a very advanced lunar civilization, and not one for an early base trying to justify its existence with useful exports to LEO or elsewhere. Alloys will come on line someday; it will take young metallurgists without defeatist attitudes ready to scrap Earth-customary alloy formulations and experiment from scratch with available elements until they have a lunar-appropriate repertoire which will serve well. But that is another story. Here we want to explore the tremendous potential of GGCs.

A “Spin-Up” Enterprise Plan

But how can we explore the potential of a laboratory curiosity? We can't. Are we to wait until we get to the Moon and then fiddle around, hoping that we come up with something before the base has its next budget review? You would think so from the present dearth of activity.

Why not haul GGC out of the lab and put it through its paces in the real world? Sure that takes money, but with a little imagination it is easy to see that GGC could become a profitable industry, here and now, on good old Cradle Earth. And if so, our newly acquired expertise and experience will be ready to go whenever the powers that be establish a long-term human foothold on Luna.

What is the realistic market potential that would justify the effort and expense of getting off our bottoms and pre-developing this promising technology now? If we are talking about something only useful for industrial construction material, then the threshold for successful market penetration is high. Our GGC products must come on-line either cheaper than every competing material or have such superior properties as compared to existing alternatives as to force potential customers to take the gamble. But to limit ourselves, especially at the outset, to such a line of products is not only accepting unnecessary barriers to success, it evidences a great lack of imagination.

Does GGC have a potential for consumer products? This is an important question, for with such products cost can be secondary to other considerations such as visual appeal due to inherent special design and style possibilities, etc. The consumer market could be a much easier nut to crack, and once established and experienced there, our infant industry would be better poised for market entry in the industrial-commercial world.

Before we speculate further, we must take a look at this intriguing new material and put it through the paces to see what we can and can't do with it. Without that, we are building castles in the air.

We have a logical plan of attack for these experiments thanks to the analogy of GGC to a long familiar family of materials with which we have abundant experience: fiberglass reinforced plastic resin composites, the stuff of which we make boat hulls, shower stalls, pick-up toppers, whirlpool spas, corrugated porch roofing, and a host of other handy products. Fiber reinforced plastics or FRPs offer the game GGC entrepreneur a handy agenda for exploring the talents of the new material.

First our enterprising hero will want to see what fiberglass-like fabrication methods GGC is amenable to mimicking. Can (or should) the still hot and workable glass matrix with glass fibers already embedded be draped over a mold to take its form, or be compression molded in a die and press? Can (or should) the glass fiber be set in the mold and then impregnated with the molten glass matrix? (The magic of GGC lies in using two glass formulations: one with a higher melting point from which to make glass fibers, and one with a much lower melting point to serve as the matrix in which the reinforcing fibers are embedded.) Can (or should) the glass fibers be first impregnated with a cold frit of the powdered glass that will form the matrix upon heating in the mold to its fusing point? Once the entrepreneur has learned which fabrication methods work best or can be adapted to the idiosyncrasies of GGC in various test formulations, he is ready for the next round of experimentation.

Fabricating a "piece" of GGC of a certain useful size and shape is only the first victory. We must learn how to machine it: can the material be sawed, drilled, routed, tapped, deburred, etc.? We need to know this before we can design assembly methods. If adhesives are to be used, what works best? Thermal expansion properties of GGC formulation will be important, as well. Once our entrepreneur has done all his hands-on homework, knows what he can do with this new stuff, and has outfitted his starter plant with the appropriate machinery, tooling, and other appropriate equipment, it's time to sit down with his market-knowledgeable partner and decide on product lines.

But let's back up a moment. We said we were going for the consumer market as the ideal place to get our feet wet, and for this market one thing is paramount: visual appeal. So we go back to the lab and start playing around with our formulations. Glass of course is easily colored. Coloring the matrix glass will not provide us with a distinctive product. But colored glass fibers in a transparent glass matrix suggest tantalizing possibilities. The fibers could lie in random directions, be cross-hatched or woven, swirled, or combed to give an apparent grain. We will want to see which of these suggestions are most practical, which have the most stunning and distinguished consumer eye-appeal, etc., all without compromising the strength of our material. As to the colors: black, green, brown, blue, cranberry, and amber would give us an ample starter palette. But before buying up binfuls of the needed ingredients we could do some inexpensive footwork, using abundant and inexpensive green and brown bottle glass for our fibers to give us a first feel for likely results of this avenue of product enhancement. Our homework done, we're ready to burst onto the world scene.

Our recycled long-empty plant (the rent is cheap and a lease wasn't necessary) has been humming for a while now. Production hasn't begun because the designers are still working on the molds and dies for the introductory product line. Buyers and outlets are being lined up. At last Lunar Dawn Furniture Company is ready to greet the unsuspecting world. At first we produce only (stunning of course) case goods: coffee and end tables, etageres and book cases and bedroom sets, etc. Then we introduce a line of tubular patio furniture that makes the PVC kind look gauche. Next we branch into an upholstered line with beautiful external frames. Office furniture, striking unbreakable fluted glass lamp shades, stair and balcony railings, and unique entry doors are our next targets. Our prices are somewhat high at first, at least with the initial lines, but we were the rage at the fall furniture show in North Carolina and the spring Home Shows in every town. Lunar Dawn takes it's place beside Early American, Mediterranean, Danish Modern, and Eighteenth Century English.

We introduce less expensive but still appealing lines and franchise our operations, targeting especially the less developed nations that need to curtail their forest-razing and which have an abundance of the raw materials needed for glass making. But we also begin to diversify into the commercial and industrial markets. We've learned to make beams and panels and now offer a whole line of architectural systems for competition with steel and aluminum pole buildings, etc. One of our branches is now marketing GGC conduit and pipe at competitive prices. Another is offering a full range of clear non-laminated safety glass for buildings and vehicles.

Meanwhile, we are not resting on our laurels in the consumer world. Casings for small appliances, cookware, ovenware, and table ware; handles, wash basins, and countertops; boat hulls for boulder-studded white water use; all are now available in GGC. A big hit with the fans is our indestructible flagship in the sports world, our GGC bodied Demo Derby Dragon. The same car has won its first dozen events and looks none the worse for it.

Of course, we've long since abandoned the cumbersome GGC or Glass-Glass-Composite tags. The public got what it needs, a simple one syllable pigeonhole. We're known and recognized everywhere as GLAX, a word suggesting glass with a difference: strength. And visually, the "ss"-replacing-"x" even suggests the dual composition involved. Glax is a generic term like steel or wool and even has its own generic logo, a symbol for public recognition and promotion.

You'll see in the logo symbol an allusion the Moon. For the ulterior motive inspiring the people behind the successful Glax entry into Earth markets was the need to predevelop a technology suited for early lunar bases and settlements. Glax will provide a relatively inexpensive, uncomplicated industry for the settlers both to furnish badly needed exports, and just as important, a whole range of domestic products that will help hold the line on imports. As such, Glax is an essential keystone in the plan to achieve economic viability and autonomy for the projected City.

There is a lot of enthusiasm on Earth now, not just for a lunar scientific outpost à la Antarctica, but for a genuine settlement. This change of attitude did not happen by accident, and the story of Glax on Earth played a major role in this turn of events. Glax, since the first door-opening day of *Lunar Dawn Furniture Company*, was aggressively marketed as an anticipatory lunar technology. The public began to get the idea that moon dust might be good for something and that the idea of a self-supporting settlement relying largely on its own resources was not a flake notion, but rather something reasonable, even to be expected! Lunar Dawn helped th process along when after moving into its brand new plant in suburban Milwaukee, it built a simulated lunar home next door, soil-sheltered and all, with solar access, periscopic picture windows, ceramic, glass, and metal interior surfaces, and of course furnished with its own Glax furniture lines. The habitat was accessed by "pressurized walkway" from the meeting hall-display room-library-computer network room and gift shop built alongside and used free of charge by Milwaukee Lunar Reclamation Society.

How did this all happen? Notice the fine print on *Lunar Dawn* ads and billboards (also used in connection with other Glax product companies): it reads "An Ulterior Ventures Company". Ulterior Ventures isn't some big conglomerate but a unique venture fund which the National Space Society helped to organize to give entrepreneurs willing to predevelop anticipated lunar technologies for Earth markets, a little help to get started. Successful members of the Ulterior Ventures family pay a royalty which helps build the fund for even more ambitious exploits. In future articles we hope to tell you about other successful -- if not so well known -- members of the Ulterior Ventures family.

Future Fact or Science Fiction?

Fiction? Yes. Unrestrained flight of fancy? No! This is the sort of thing that could happen with NSS encouragement, if the society can be persuaded to show the same enthusiasm for direct action as it always has for indirect agitation "to make it happen". Having to start from scratch to build the infrastructure to incubate and support such "ulterior ventures" would mean an unwelcome set-back in time, effort, and personal energies.

The brand new infant industry sketched above does not require expertise in preexisting sophisticated technologies to get started. Almost any of use could get in on the ground floor of such an endeavor in one or more capacities. Any takers? -- Peter Kokh May 1988

JEWELRY

Dressing Up in the Settlement with “Made-on-Luna” JEWELRY

By André D. Joseph and Peter Kokh

For some, nothing in life could be more unimportant or irrelevant than jewelry. They would prefer to do without, thank you. For others, it is a matter of putting on the dog, of asserting status, class, sophistication -- something more than individuality. Then there are those gypsy-kindred souls who only seek cheerful decoration and for whom the true or perceived market value of their baubles is meaningless.

No Gold, Silver, Platinum, or Copper Using Iron, Aluminum, Magnesium instead

What materials can Lunan artisans use to create ornamental items to wear? The time-honored jewelry-making metals of Earth - gold, silver, platinum, copper - and their alloys will be extremely hard to come by as they would seem to be present on the Moon only in minute, non-concentrated traces. Magnesium can be worked if it is heated to about 400° F but is dangerously reactive with the oxygen in the air [magnesium is the basis of fireworks.] But Aluminum, that once precious but now mundane and pedestrian commonplace, can be worked cold. So we might assume that some aluminum alloy would become the metallic medium of choice for the jewelry maker in Luna City. But bear in mind that iron will be the cheapest metal to produce on the Moon and here and there in Earth’s past it has been pressed into service of adornment.

Diamonds and Gemstones

Given rediscovered metals to work with, what can be added? It is probable that diamond *dust* of meteoric origin is a widespread trace. But diamonds of visible size seem unlikely, as they are constituted carbon, with which the Moon is not naturally endowed. Synthetic diamonds and cubic zirconium? In time, perhaps, when there are enough settlers and enough demand. Many other gemstones such as ruby, sapphire, amethyst, agate, onyx, jade etc. might possibly have formed at great heat and pressure deep within the Moon and brought towards the surface, as on Earth, by past episodes of volcanism. The elements for their recipes are certainly present,. But we won’t find them on the highly pulverized surface. Just possibly, future Lunan “spelunkers”will find some here and there in the lava tubes we know to be present in the layers of solidified mare lava sheets. If not, synthetic rubies and sapphires can be made from aluminum oxide (corundum.)

Pearls?

At a premium representing the non-native carbon ingredient, pearls could be cultivated in lunar oyster beds. At a similar premium for non-native carbon content would be dried and carved peach pits, a Chinese art form, and small decorative items made from such hard and richly grained orchard woos as apple, pear, and cherry. Indeed, given its character and the pressures for not withdrawn it in quantity from the biosphere cycle, would might be one of the most sought after media for bauble-making on the Moon or in free-space oases.

Ceramics and Glass

By far the cheapest “stone” will be such all-native-content creations such as glazes ceramics, synthetic crystals and clear colored glass. Gems of “paste” are actually a very hard form of glass with a high lead content. Lead will be quite scarce and potash glass might be the next choice. Another route will be vitreous enamel glazes on metal similar to cloisonné but filing carved *bas relief* bays in the aluminum rather than bays created by superimposing gold wires on a brass base.

As was already mentioned in a previous article “Apparel” [MMM #13] glass bead work and metal chain mail will certainly be viable forms of expression for frontier artisans. Perhaps, too, some ordinary moonrock breccias, when cut and polished will have satisfying appeal.

Play Jewelry

For temporary recyclable “play jewelry,” gaily colored papier maché items, maybe glitzed up with seeds and kernels, would be one choice. And a necklace strung with bits of pyrites (FeS, fool’s gold) might bring a smile to any Lunan lass.

Concentrating on the practical

Jewelers might concentrate on more practical items such as buttons, belt buckles, hair clips, scarf rings etc. than on purely superfluous items as necklaces, bracelets, rings, broaches, and earrings. Making artfully what must be made anyway is a more honest function, and these sorts of values will be a badge of the frontier. Jewelry of export will serve mostly a souvenir function, until the proficiency of Lunar artisans working in new media comes into its own. MMM 5/88

A Logo for the *Ulterior Ventures Fund* suggested in the previous article on Glass Glass Composites.

The larger downward arrow, for the terrestrial applications that support the research and development, give rise to the upward arrow, putting “on-the-shelf” technologies that will be needed on the lunar and space frontiers.

Interest and/or royalties on venture funds will support further ventures.

Activist Polycentrism, and the Highest United Multiple

Commentary by Peter Kokh

For some strange reason, some people have a driving need to *impoverish the universe* by insisting that everyone agree on some anemic unified approach "so as all to pull in the same direction." The only thing available down this road, folks, is the *least common denominator,* something cherished by small stingy minds. It is true, that where we *must* act as a unit, that's all that's available.

But if we truly want to build a rich, full, diversified spacefaring future, the best approach is to allow individual and local talents, interests and energies to work themselves out. This will bring to light a whole wealth of things that could never be begotten by any unified *top-down* plan which puts all its eggs in one fragile basket. Many people fear diversity, insisting it can lead only to conflict and mutual destruction. *Wisely nurtured, diversity cross-fertilizes insights, talents, and energies to lead to the "Highest United Multiple,"* which beats the diaper-load out of the lowest common denominator approach any day!

To be concrete: our Society is made up of thousands of persons with diverse talents. Many would reduce that to *controllable* (read "sterilized") numbers of letter-writers and phone-callers and money-givers, That's all we are to some of our self-appointed elite. How pathetic. Let's instead put all this rich and diverse talent to use!

Our Society headquarters is small-staffed and limited in what it can do. If we see a useful project (that we can *see* it suggests that we may just have the talent and ability to tackle it) we are wasting our time *and passing the buck* if we want to foist that pet project on headquarters, or on the Society as a whole. As individuals -- better yet, as chapter members -- we must bite the bullet and follow the guide star of our own talent-lit insights. For individuals, that might mean getting out of the armchair. It might mean weaning ourselves from the search for excuses and reasons why as chapters, we can't do something useful ourselves.

Look at the rich variety of prospering chapter endeavors already begun! Pikes Peak's (Colorado Springs) Hummingbirds project; Tucson SFS' Technopolis project and its efforts to translate space publications into Spanish; Oregon L5's simulated lunar base in a lava tube complex near Bend; Seattle Lunar Group's (SLuG) research on architecture with lunar resources; Milwaukee Lunar Reclamation Society's effort to identify technologies needed for lunar settlement that might be pre-developed for profitable terrestrial applications. Other chapters are taking the initiative in yet other imaginative ways. Hey, *we don't all have to fit into someone else's underfed universe!*

Yes, some projects may be too big for a chapter. The answer is either to grow locally (enlisting the talent you need) and/or to network: chapters with common interests can work together on some project too demanding for any one of them. For example, Tucson could use help translating space materials into Spanish. Cincinnati L5 which puts out its *TEACHING SPACE* newsletter, might network with other chapters interested in creative space-education efforts. Organizing a funding infrastructure to support the Lunar Polar Orbiter effort or promising entrepreneurial ventures might be a joint project. The possibilities are endless. Our Society can only thrive on such *bottom-up* polycentrism!

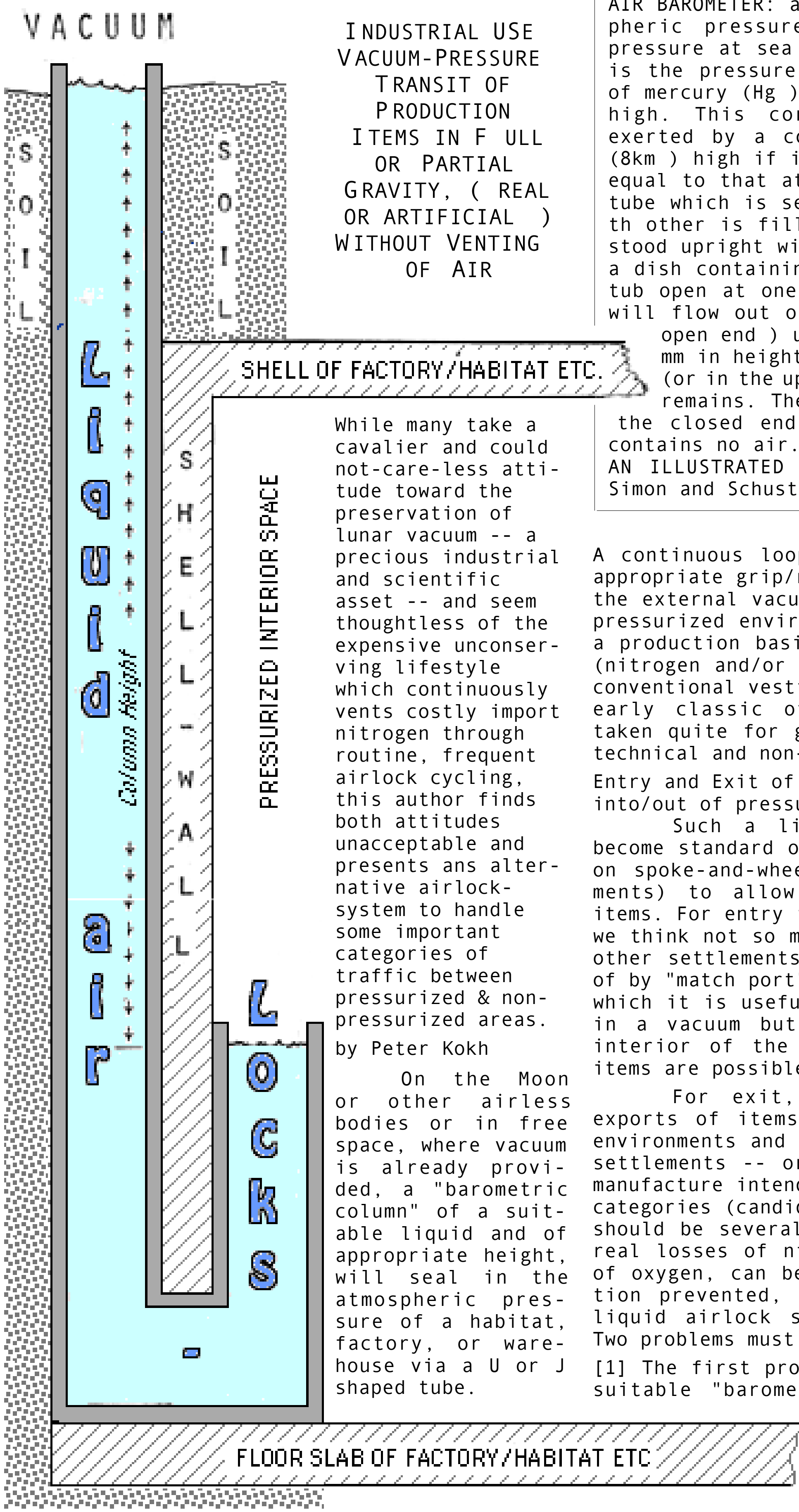
Our nation was built not on top-down mandates but on bottom-up inspirations. As a Society, we must likewise seize the initiatives to which our talents and energies are tailored. And the leadership of our Society should encourage, foster, and facilitate such cross-fertilizing diversity, rather than discourage and disparage it. This is not "discord." Discord enters only when someone tries to reduce someone else's vistas to one's own presumptive worldview. As a Society, we must not fear diversity but welcome it. *It is our Ticket!* -- Peter Kokh 7/88

MAIL to MMM: The Moon's Atmosphere

I have been following MMM's debate on the use of nuclear power on the Moon. There seems to be the assumption that because there is no sensible lunar atmosphere, there never will be. Once we come to stay, however, that could change. The natural lunar atmosphere weighs about 10 tons, with a replacement and loss rate of about 50 grams per second. Most of it consists of solar wind particles enjoying a brief rest before rushing off again, and radioactive decay products such as radon waiting to be photoionized off into space.

Humans will probably be far messier than that. Gasses from pressure hull leakage, regolith processing, rocket exhaust, etc. will outstrip natural sources by several orders of magnitude. Unless we're exceedingly careful, the natural atmosphere would soon be merely a trace element in a man-made one that will be thick enough to stop the solar wind and some UV from reaching the surface. Under those conditions the lower portions of this nouvelle atmosphere will be protected from the main loss mechanisms and the stay time of typical air molecules may rise from weeks to millennia.

The future history of the Moon's atmosphere is hard to predict, depending as it does, on human activity and on the unknown absorptivity of the lunar surface. I don't suppose the air will ever get thick enough to tempt one to go outside sans spacesuit, but there will be enough, someday, to require appreciable changes in lunar hardware and operations. A thousand years from no, Earthlings may look up to see not only the lights of lunar cities, but also the ruddy, oxidized disc of a deeply tanned man-in-the-moon. *Joe Suszynski*



INDUSTRIAL USE VACUUM-PRESSURE TRANSIT OF PRODUCTION ITEMS IN FULL OR PARTIAL GRAVITY, (REAL OR ARTIFICIAL) WITHOUT VENTING OF AIR

While many take a cavalier and could not-care-less attitude toward the preservation of lunar vacuum -- a precious industrial and scientific asset -- and seem thoughtless of the expensive unconserving lifestyle which continuously vents costly import nitrogen through routine, frequent airlock cycling, this author finds both attitudes unacceptable and presents ans alternative airlock-system to handle some important categories of traffic between pressurized & non-pressurized areas.

by Peter Kokh

On the Moon or other airless bodies or in free space, where vacuum is already provided, a "barometric column" of a suitable liquid and of appropriate height, will seal in the atmospheric pressure of a habitat, factory, or warehouse via a U or J shaped tube.

AIR BAROMETER: a device for measuring atmospheric pressure. The average atmospheric pressure at sea level is 1 atmosphere which is the pressure that will support a column of mercury (Hg) 760 mm (76 cm or 29.92 in) high. This corresponds to the pressure exerted by a column of air about 5 miles (8km) high if its density were constant and equal to that at sea level. If a long glass tube which is sealed at one end and open at th other is filled with mercury and then is stood upright with the open end downwards in a dish containing mercury (or in a U-shaped tub open at one end) then so much mercury will flow out of the tub (or up the other, open end) until a column of mercury 760 mm in height above the level in the dish (or in the upturned open end of the tube) remains. The space above the mercury in the closed end of the tube is vacuum and contains no air. From: THE WAYS THINGS WORK, AN ILLUSTRATED ENCYCLOPEDIA OF TECHNOLOGY, Simon and Schuster, 1963. Page 220.

A continuous loop conveyor provided with the appropriate grip/release system with one end in the external vacuum, the other in the internal pressurized environment, will allow transit on a production basis without the venting of air (nitrogen and/or oxygen) such as occurs in the conventional vestibule-type cycling airlock, an early classic of science-fiction and still taken quite for granted by most writers, both technical and non-technical alike. (For Shame!)

Entry and Exit of "Routine Items" into/out of pressurized environments

Such a liquid barometric seal could become standard on the Moon (and, for example, on spoke-and-wheel shaped free space settlements) to allow entry and exit of routine items. For entry into pressurized environments, we think not so much of imports (from Earth or other settlements) -- these can be taken care of by "match port" docking -- as of those items which it is useful or efficient to manufacture in a vacuum but which will be used in the interior of the settlement. Metal and glass items are possible instances.

For exit, we think not so much of exports of items manufactured in pressurized environments and intended for use *within* other settlements -- or vehicles -- as of items so manufacture intended for use in vacuum. Of both categories (candidates for entry or exit) there should be several if not many instances. Very real losses of nitrogen, especially, but also of oxygen, can be avoided and vacuum degradation prevented, by the employment of such a liquid airlock system in well chosen cases. Two problems must be discussed.

[1] The first problem is the availability of a suitable "barometric" liquid. Such a liquid should be fluid over a wide range of tempera-tures so that its utility is not constrained. A relatively high specific gravity or density would be a plus because it would

proportion-ately shorten the required sealing column. It should have a low vapor pressure so that the rate at which it evaporates into the vacuum is slow enough to represent a substantial savings over the continual nitrogen loss that would result from the alternative reliance on a conventional cycling airlock system. Its cost of acquisition, by upport from Earth or by lunar sourcing should again be lower than the cost of the nitrogen conserved over the life-time of its use.

[2] Finally, such a liquid should be relatively inert, not corroding or otherwise adversely affecting either the items carried through it or the conveyor that carries them. It should drip off the exiting parts easily, both in vacuum and in air.

Candidate Liquids

Three possibilities suggest themselves. The first is Mercury (Hg), the densest choice by far. However, it is highly unlikely that mercury can be lunar-sourced. The cost of its upport must be added to that of its acquisition (purchase), and very large volumes of it will be needed, the cross-section of these industrial-scaled liquid airlocks being orders of magnitude larger than that of barometers and thermometers. Finally, mercury has a highly toxic reputation -- well-earned -- that would require very special handling on both ends. Despite its high specific gravity, we can pass over this choice.

The second choice is Gallium (Ga) which before its expected discovery was referred to as eka-aluminum. This element is very scarce but widely distributed on Earth in zinc blends and bauxite. Traces of it have been found in lunar soils, but it may be some time before it can be extracted economically in the quantities required for this prospective use which would be in competition with its desired service in gallium arsenide photocells for solar arrays (more efficient than the far cheaper silicon). Which usage would be more strategically important, I am not prepared to guess.

The credits of gallium are considerable. It is liquid from 30.1 °C - 1983 °C (86 °F .. 3601 °F) -- a very serviceable range for lunar and free space environments and industrial conditions -- and has a very low vapor pressure. Its specific gravity as a liquid is 6.081 (times as dense as water), which is very attractive, if somewhat less than half that of mercury. Of its inertness and benignness, I would not know.

The third choice is NaK (pronounced "knack"), a eutectic liquid alloy so-called from its constituents: sodium (Na) 23% and potassium (K) 77%. NaK, unlike its constituents, is liquid from a temperature not much higher than room temperature to about 800 °C -- again a highly serviceable range. Its thermal capacity is high. This, together with its expected economical lunar-sourcability will make it the industrial coolant of choice (instead of water/steam) for many lunar applications, possibly nuclear reactors among them. Against its cheapness as compared to other choices, Hg and Ga, must be balanced its low density or specific gravity which is comparable to that of water. This means that for its use in a barometric sealing liquid airlock system, the necessary column must be six times that of a system using gallium, and nearly fourteen times that of a system using mercury.

Nonetheless, while far from ideal, such high columns are still within the realm of practicability. Given the importance of the strategic goals (conserving nitrogen and preserving vacuum), all else considered, NaK is the logical choice. Possible showstoppers are its degree of inertness *or lack thereof*, of which I am ignorant, and the evaporation rate in vacuum, of which again I know nothing. As to its density, suffer a layman's naivete to suggest experimenting with solutions of NaK and sodium disulfide or potassium disulfide, which might raise the value to a more practical level.

HEIGHTS OF BAROMETRIC SEALING COLUMNS
IN VARIOUS GRAVITY AND PRESSURE SITUATIONS.

(The height is shown in meters with foot' and inch" equivalent given in parentheses)

Gravity: Earth-like situation (1.0 g)

Pressure:	1.0 ATM		0.5 ATM	
Liquid				
Hg	0.76	(29' 9")	0.38	(15' 0")
Ga	1.74	(58' 5")	0.87	(34' 2")
NaK	10.33	(33' 9")	5.17	(17' 5")

Gravity: Mars-like situation (0.38 g)

Pressure:	1.0 ATM		0.5 ATM	
Liquid				
Hg	2.00	(78' 7")	1.00	(39' 4")
Ga	4.58	(15' 0")	2.29	(7' 5")
NaK	27.18	(89' 0")	13.59	(44' 5")

Gravity: Moon-like situation (0.16 g)

Pressure:	1.0 ATM		0.5 ATM	
Liquid				
Hg	4.56	(15' 0")	2.78	(7' 5")
Ga	10.44	(34' 2")	5.22	(17' 1")
NaK	62.00	(203' 0")	31.00	(101' 7")

Note the extra incentive (besides the 63% savings in nitrogen upports) that the lower column height in 0.5 ATM provides (0.5 ATM consisting of 21 parts oxygen and 29 parts nitrogen or 50/100 ATM vs. 1.0 ATM consisting of 21 parts oxygen and 79 parts nitrogen or 100 / 100 ATM). NASA suggests this mixture as quite livable.

Application on Rotating Structures with Artificial Gravity

In rotating space structures with artificial gravity, the motivation to preserve the external vacuum disappears, but the economic necessity of conserving nitrogen remains, and the barometric seal liquid airlock will be a wise choice for the appropriate categories of goods traffic. The figures given above are valid to this venue as well. Thus a torus with 1/6th gravity (Moonlike) and 0.5 ATM internal pressure could be outfitted at each spoke with a liquid airlock with one end inside the torus and the other end piercing the ceiling on the side of the spoke and with a 101.7 foot column differential using NaK. This might come in especially handy for parts manufactured inside the rotating settlement for use in adding on to it from the outside. For a full 1.0G 1.0 ATM Stanford Torus, the corresponding column height would be 33.9 feet. The height in both cases seems eminently practical.

For Bernal Spheres and O'Neill Cylinders, liquid airlocks can still be used, but they must creep up the outside of the end caps and will be a mite tricker to use. To my knowledge, no one has discussed the possibility of liquid airlocks for either space settlements or lunar installations.

Application on Other Airless Worlds

The applications on other large airless satellites (Io, Ganymede, Callisto, and Europa in descending order of gravity) will be quite similar to those on Luna. But smaller bodies, e.g. Ceres, Iapetus, etc. will require column heights that would seem quite impractical -- many hundreds of feet or more. Economics will determine the cut-off point.

Engineering Challenges

The second problem -- for those of you waiting for the other shoe to drop -- is that of inventing (and patenting) the appropriate conveyor system with a grip / release system that probably must be design-specific for each type of production-line ware making the transit inwards or outwards. As we are dealing with a a system open to vacuum on one end, the whole must be as thoroughly service-free as possible and operate without snags or jams. Here is where this neat idea must descend from the head-in-the-clouds abstract to the nuts-and-bolts concrete. The liquid airlock idea may be patentable in itself, but I doubt it, and the need for the real world experimentation is paramount; hence the lack of hesitation in throwing it out into the public domain.

Getting your feet wet -- *Experiment!*

For those of you itching to experiment with different liquids and diverse conveyor systems, but requiring the possibility of profits from here-and-now terrestrial applications markets, here are some possibilities to spur on this pre-spin: transit between everyday Earth environments and special atmosphere chambers using pure nitrogen, pure chlorine, pure hydrogen, or other gases; transit into and out of "clean rooms".

Such applications may seem sparse, but I venture they will be deemed important enough -- at least in some high-traffic instances -- to support the costs of research and development necessary. If this is indeed the case, here are avenues of experimen-tation which will put invaluable experience and know-how "on the shelf" from where we can take them, at greatly minimized cost and delay, when we need them for space or lunar use eventually. Another important ULTERIOR VENTURE entered into for profit below and ulterior utility above. If we leave it to NASA, It wouldn't get done! It's not a need for a non-industrial outpost such as NASA has limited its vision to include. < MMM >

Moon Miners' Manifesto # 18, September, 1988

LPO Report to our Members: Proposed Chapter Participation in a Workshop to Design & Fund a Private Lunar Orbiter

[The birth of the grass roots effort that culminated in *Lunar Prospector* and its successful mission in 1998.]

by Peter Kokh

While NASA continues to have one amazing success after another in Solar System *exploration,* probes aimed at uncovering the information upon which to base *development* continue to occupy the lowest priority on the Agency's agenda. If, and only if, the planned *Mars Observer* (now set to go up on a Titan in 1992, but threatened with further postponement) is successful, a *backup craft may* be re-targeted as a *Lunar Polar Observer* with the earliest possible (unlikely!) launch date in 1994. Such a probe *would* do the trick, orbiting the Moon's poles with the necessary instrumentation to detect any *water-ice deposits accumulated in lunar "permashade" areas,* as well as doing a complete, and badly needed *geochemical mapping* of the entire globe.

We cannot finalize plans for a Return to the Moon *to Stay* without the information, be the answer affirmative or negative, that such a prove would provide. The longer such a probe is postponed, the further into the 21st Century slips the ground breaking for the first permanent manned outpost, and beyond that, the long-awaited deep Farside astronomy complex, and genuine settlement in general. Thus the impatience of pro Lunar Development people to see if we can't design, build, and fly such a probe with largely off-the-shelf instrumentation on available small satellite power bus with minimal launcher.

Is our confidence that we can pull off such a feat well-grounded or pretentious foolishness? Consider the team that Dr. Gay Canough (rhymes with "enough")(a high-energy physicist from ExtraTerrestrial Materials, Inc. [ETM]) has been assembling since the Denver International Space Development Conference at the end of May, this year:

- Mission Profile people from Caltech's Jet Propulsion Laboratory (JPL) and Space Studies Institute (SSI)
- Instrumentation people from ETM, Fermilab, and EG&G (manufacturers of the key gamma ray spectrometer instrument)
- small satellite power bus people from American MicroSat, GlobeSat, and AMSAT.

This is certainly a team of sufficient competence and expertise to design and build the probe. It will be the job of this "Instrumentation Team" at the workshop, to choose among the several possibilities, and precisely define the probe and its mission.

Our friends in the American Lunar Soc. headquartered in East Pittsburgh will be on this team. Seattle L5 Soc., with more technical people than the Milwaukee Lunar Reclamation Society may have a contribution to make.

Once the cost of hardware acquisition and assembly is worked out, the big trick will be to find a way to pay for the probe (estimated at $3-7 M) *and* the launch (estimated $15-40 M.) While this is a whole lot less money than NASA would need to do the same job, it is still a formidable amount. Consider that the Challenger Center is having a hard time raising a similar amount for a worthwhile cause!

Here is where the Milwaukee and Seattle chapters can contribute. (No, not with the money! - we live hand to mouth!) with ideas for hitherto untapped funding sources. It was one of these ideas (whether it ultimately pans out or not is unimportant) that was the spark that relit the cold embers from last year's aborted effort (launched at the 1987 Pittsburgh ISDC) to do the same thing *with NSS support* which was not then forthcoming.

A Spring Rendesvouz in Clear Lake, TX

While optimism is not by any means a predictor of success, it is clearly the appropriate attitude. So with the hope that chapter people can attend the workshop, to be hosted by the Houston Space Society at Clear Lake next spring, and present a well-thought out multi-angled funding strategy *as a basis for further discussion* by the workshop participants, it is vital that we begin our homework now.

At the regular MLRS meeting Saturday, September 10th, 1-4 pm (Old Board Room at the Milwaukee Central Library) we will put together a crude first draft proposal that can then be sent to Seattle L5 (our MMM partner) in time for their next meeting and further work: then back to Milwaukee for the October meeting etc. until the time of the workshop in Houston. We can hope that some of our combined brain-racking will prove to be helpful to the effort.

QUESTIONS to consider

- Should funding for the the orbiter-probe and funding for the launch be separated (do they lend themselves to different approaches? to different sources of funding?)
- How important will be a Project Name and a name for the Probe itself?
- Should the project be International in scope?
- Can an incentives program be developed?
- We'll need a strategy that targets individuals, corporations, foundations and philan-thropists etc. How should a fund be set up legally, and under what agency or *aegis?*

Start pondering these questions and contribute your two cents worth at our upcoming meetings, or by phone to Peter in Milwaukee, or Hugh in Seattle or by mail. Please don't assume that someone else has already thought of your idea. Our goal is too important to risk failure through mistaken assumptions! -- PK 8/88

A Strategy For Following Up Lunar Soil-Processing With Industrial

M.U.S.-c.l.e.

by Peter Kokh

How can a small settlement (anything less than some hundred of thousands and probably a whole lot smaller) have the most effect industrially? Some "muscle"? Fortunately, we have a clear and precise criterion by which to judge, and it points the way like a beacon: keeping upport tonnage from Earth to a minimum, i.e. making do for as much (mass-wise) of the settlement's needs as possible from local lunar resources. To strive in this direction, the settlement -- while not neglecting any possibilities -- will do well to give top priority to items which, multiplying unit weights by quantity needed, embody the greatest opportunity for savings if manufactured locally.

Among equally weighty categories, those items that require less industrial sophistication and diversification and which are not unreasonably labor intensive would naturally get first attention (e.g. one ton of dishes over one ton of electronics).

Shelter itself, with some parts of utility systems (e.g. pipe and conduit at least), and basic furniture and furnishings made of 'lunacrete', iron and steel, ceramics, glass, fiberglass, and glass-glass composites (glax) are obvious items on the list. Such things should account for most of the settlement's physical plant.

What about sophisticated products: machinery of all sorts, vehicles, electronics, appliances? Too ambitious? Only for the unresourceful! Consider that every supposedly more involved product is an assembly of parts that often includes a shell, casing, cabinet, body, hull, table, etc. that is less complex and yet often represents a considerable part of the total weight of the item. If such parts were made in the settlement and final assembly done there (the really complicated and sophisticated portions representing the output of ny subcontractors being preassembled on Earth in subassemblies as large and as integral as possible) this would hold down the principally weight-determined upport price of everything from major shop tools to telephones to vehicles.

This would mean standardizing the size and interfaces of upported subassemblies, cartridges, chases, etc. to fit the very minimal number of cabinet, casing, and body models, etc. that the small lunar work force could produce. (If the completed item were upported, parts supply would be the only limiting factor on variety). Even so, "standard" cabinets and casings could be made to take varied finishes, textures, and colors.

Now the way we make many items on Earth, especially electronics, would lend itself to this approach. Of course, a central office (on Earth would save lunar manpower from paperwork) would have to coordinate everything, so that only chases and work-trays, etc. that would fit made-on-Luna casings and cabinets would be upported. This should not be hard to arrange on a bid basis.

The weight savings on major appliances in cases in which the settlement is not yet prepared to make more than the housing should be considerable. Many such items could be redesigned so all the sophisticated "works" are in one or a few slip-in cartridges.

By the way, all this reasoning holds just as true if it turns out that the first off-Earth settlements are in free space colonies rather than on the lunar surface. Such settlers would operate under the same restrictions until their numbers are vast enough to support self-manufacture of all their needs. They too will need the right strategy to build industrial "muscle".

Why not vehicles (both surface and intra-biosphere) with the body or coach made on the Moon, designed for easy retrofit of a cartridge-like wiring harness, control panel / dash, and motor (even here major heavy parts could be locally made and designed for ease of final assembly)? The benefits of such a setup would be immense.

To maximize the possibilities for "lunar content" and the ease of final local assembly will require designing such vehicles from scratch with this very goal as utmost priority. In a future article, we will talk about the need for an agency to take the initiative in stockpiling such "cartridge designs" for future lunar need.

Keep in mind that lunar surface vehicles *are* vacuum-worthy spaceships. So the next step would be Earth-Moon, or rather LEO, low-Earth-orbit to Moon or lunar orbiting depot) ferries of high lunar content (cabin, hold, tankage, etc.) and then even space station modules for LEO and GEO designed for easy snap-in outfitting of "works" from Earth.

"M.U.S.-c.l.c." 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 mating 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 withstand the inevitable public loss of interest when they find out just how hostile a place 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.

The Further Contribution 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 seismically 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 intermediate 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*.

t 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 postponement), *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).

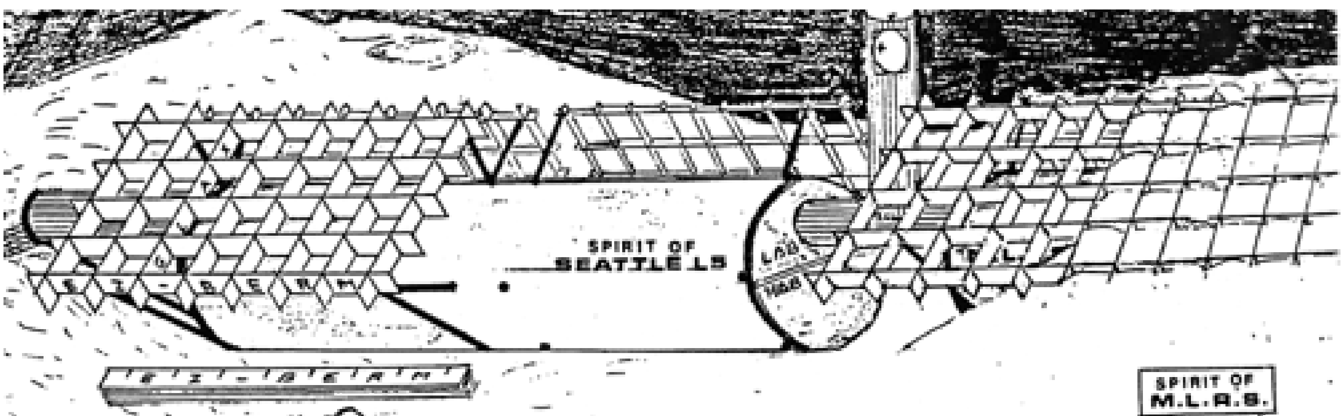
Phobos: Fly in the Ointment?

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 ambi-tious 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



1) Welcome to Seattle L5/1
2) Illustration of Berm Concept

With this Issue, MMM Welcomes the Seattle L5 Society and its Members to our now joint newsletter.

With the September issue, Moon Miners' Manifesto starts service to the Seattle-Tacoma-Puget Sound area of Washington State. We trust our new readers will enjoy our collaboration. For those of us who've been getting MMM for some time, there's a big plus for us too! We'll now get the column of Arft Bozlee, top Soviet Space Expert, and "Family Science" by Georgia Franklin, starting next month [#19].

The Seattle L5 chapter was the first to be founded, and has long been interested in a return to the Moon. SL5 has a very active research group exploring the possibilities of Lunar-appropriate architectures: the Seattle Lunar Group - SLuG, affectionately named after the Puget Sound area mascot :-) We hope our new associate editor in Seattle, Michael Thomas, will give us the scoop on SLuG.

At the National Space Society's recent International Space Development Conference in Denver, Hugh Kelso of Seattle formed part of the "K Team" with editor Petr Kokh and fellow Milwaukeean Mark Kaehny who together managed to ressurrect, at the conference, the effort to build anjd fly a private Lunar Polar Orbiter. *May our interchapter collaboration continue to bear much fruit!*

This month, Milwaukee Lunar Reclamation Soc. also launches a sister-chapter link to Queensland NSS, Brisbane, Australia! *G'day to our fellows space-enthusiasts down under!*

NOTE: With this issue, we change gears a tad. We had finally taken the computer plunge and graduated from my aging IBM Selectric Typewriter to a new Commodore 64 ("64 K, all the memory one could ever want.") And with it, we changed fonts, to a modified Courier. To reflect that, we now switch from Andale Mono 9 to Courier 10.

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 achievement 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 reusable 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 continued 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 inapropriate 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-approaching 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 accessible 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 scenario by which a solar system ranging civilization might arise despite such handicaps. 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 they 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.]

Colonist 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 transfer 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 commonly 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 possibility, 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 tectonics involving continental plate drift, well-lubricated by an ample hydrosphere, the ocean. This process never occurred on the Moon, but may have operated sputteringly on Mars for a comparably brief period. It is an outside 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 Labyrinthus, 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 extensive permafrost, ice-saturated ground, but do not know its extent, its nearness to the surface, its concentration (percentage 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 practical source, detailed altimetry mapping of the lay of the land will determine 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* Conferences 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 planning 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 expedition 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 expeditions and less dangerous. The government(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 telescience 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 (monitoring 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 radioactivity 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 (CH4) and ammonia (NH3) 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 manufacture 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) A Feasibility Lab: 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) An Experimental Farm: 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 (CO2) 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) High Capacity Computer Facility: 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) Homework 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) Ongoingbuilding 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 respectively met with with most stubborn resistance. 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 equivalent 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, whether we are there yet or not, 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 9/88

NOTE: The Author has since (1999) reworked these ideas to maturity. You can read about "**The MarsPulse Calenda**r" online at:

http://members.aol.com/tanstaaflz/marspulse_cal.htm

Wooing the Astronomical Community

Commentary by Peter Kokh

Most of us know one or more amateur astronomer friends, who are oddly aloof to the cause of the space frontier, if not openly hostile. For those of us who come to the space movement out of a prior interest in astronomy, myself included, this seems puzzling indeed.

To us, studying the stars and wanting to go out there are one and the same.

But there are reasons for the uneasiness some of these fellow spirits show around us, and with a little self-examination, they are not hard to find.

Above all, we are identified with the manned space program, which since it has been forced by bureaucratic mischief to drink at the same budgetary fountain as unquestionably deserving planetary exploration robes, is cast as the rival, instead of the natural ally that common sense indicates it should be. Now, while most of us are very much interest in, and enthusiastic about planetary exploration probes, *we have been guilty of not working hard enough to isolate the planetary exploration part of the budget.*

As a Society, we have been complicit by negligence. Yes, we have endorsed the National Commission on Space Report and the Sally Ride Report but this does not address the problem. Perhaps we've been too busy fighting the effects of the NASA budget's mischievous pairing with that of HUD. In both cases, we've made a lot of noise about symptoms and not made nearly enough nuisance of ourselves concerning the root cause. The Society needs to speak out in its policy positions, both in favor of a more ambitious planetary program, and above all in favor of its budgetary independence. Even the choice of missions should be made apolitically; perhaps, for example, by the National Science Foundation in consultation with planetary scientists, and not be forced into some demeaning swimsuit beauty contest before jades congressionals. *We've been letting others trap us into the zero sum game.*

But secondly, and even more importantly to some, we (at least those of us who come from the former L5 Society) are identified with a plot to destroy forever the beauty of the night sky (at least the night sky far from city lights) by planning and/or supporting the deployment of an orbital necklace of solar power satellites, each far outshining Venus, and perhaps relegating the Milky Way to a racial memory. *The fault here to lies in negligence, this time on the part of the former L5 Society and of Space Studies Institute.*

Recently, the solar power satellite concept has had a through overhaul by Space Research Associates in Seattle, working under an SSI grant, to identify ways in which the lunar-sourceable content of such structures could be maximized. This study was quite successful and defined an SPS that was 99% lunar-sourced (as an improvement over 90%) at only an 8% penalty in extra mass. *This encouraging reworking of the flagship concept of space development needs an encore.*

For the task now at hand is once again to rework the entire SPS design concept, this time, in an effort to define *design and construction alternatives that will minimize the visual intrusion of an SPS unit in Earth's nigh sky.* We call for a design goal of a *reduction in apparent magnitude* (without reduction of power rating) of at least 5 magnitudes, that is, *a hundredfold dimming.* If we go to parabolic collectors for solar turbines rather than stick with photovoltaic designs and if we look for other places where albedo changes can be made, such a drastic goal might be approached, who knows, surpassed.

If we love the stars, we should spare no effort to preserve our ancestral right to see them.

Which bring us to a point well taken by Diane Fearne-Desrossiers of Lansing L5, Michigan: "how can we expect city dwellers to be interested in space, when we can no longer see the stars from within the city? *We ought to join ranks with those in the astronomical community fighting sky pollution* from unnecessary use of unshielded and high-pressure sodium vapor city lighting." If those in San Diego and Tucson who have fought the good fight and won would be so kind as to give the rest of us a primer (background knowledge so that we will know what we are talking about, plus campaign methods) we'd be on our way to restoring dark skies and the lure of the stars to all our land.

Finally, we call on the Society to augment our policy position in support of a permanent manned Moon base, by coupling to it, support of a farside radio and optical astronomy facility. Optical? Yes! From the prime sites in Aitken crater and Mare Ingenii/Thomson crater, the nearest satellite galaxies to our own, the Large and Small Magellenic Clouds, are always above the horizon, ideal for a dedicated observatory.

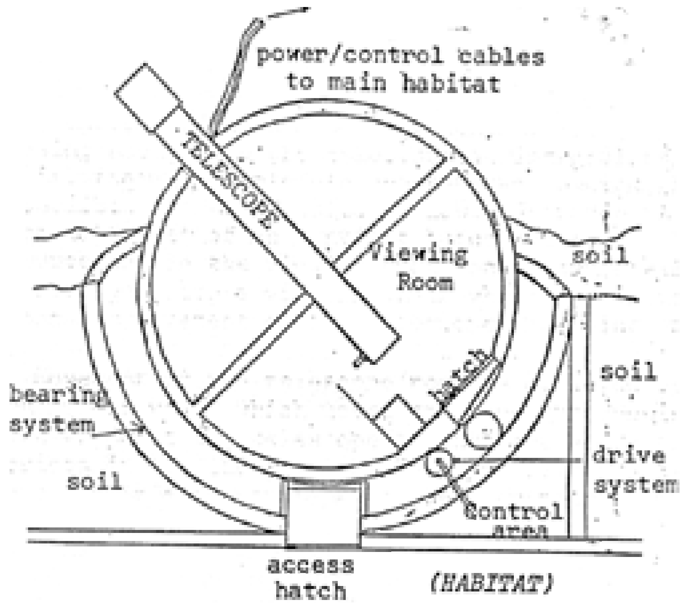
Some will caution us to secure one step at a time! But it is a mistake to seek any goal without the guidelines demands by the next step clearly in sight. This coupling can only serve to make the case for a Moonbase stronger, not weaker. This second lunar outpost, possibly inter-mittently visited at first, would do much to burst open the lunar frontier.

Yes, there are those who would seek an unmanned farside astronomy facility, and those who would ban human presence on the Moon altogether. But the penalty for this thinly disguised contempt for civili-zation is a far more limited installation than one that is human supported, and eventually staffed.

If leadership from elsewhere does not rise to the occasion, we recommend that the Milwaukee Lunar Reclamation Soc., aka NSS-MIlwaukee, consider announcing and hosting a workshop to design such a far-side installation, in bare essential form and in successive stages of expansion. The purpose would not be to come up with a final design, but to illustrate the possi-bilities with the expectation that they will enkindle enthusiasm To such a work-shop, our friends in the astronomical community would be invited to take the place of honor.

We said "if." How long should we wait out of deference? Not long! An ideal target date for such a public announcement is fast approaching: *October 4, 1989 will be the 30th anniversary of Luna 3, and mankind's first photographic glimpse of the Moon's farside,* shrouded in mystery from time immemorial up to that day. And just around the corner, this coming Christmas holiday, is the 20th anniversary of the first direct human observations of the farside by the Apollo 8 crew. - MMM

AN AMATEUR LUNAR TELESCOPE DESIGN



Submitted by Milwaukee School of Engineering (MSOE) student and MLRS member Ron August of Hubertus, Wisconsin, this concept involves a moving, spherical shaped viewing room, with the telescope an integral part of it, that is completely pressurized, heated, and accessible from the habitat below. Entrance to the room is by way of an airtight hatch system.

Once inside the viewing room, the observer will be strapped into a viewing chair which has all controls for movement of the telescope (and viewing room) and focusing of the telescope.

Movement of the telescope/room is achieved by a controller wheel which moves the room into position to point the tele-scope at anything above the horizon in all directions. The room is suspended by a low friction smooth-running bearing system.

This was the winning design in a competition cosponsored by MLRS and the American Lunar Society. Two other entries received honorable mention, including one in which a zenith-pointing telescope had its base within the habitat, the shaft piercing the regolith shielding overburden and open to the vacuum. The scope turned in a sleeve using a barometric liquid seal (see MMM #17 "Liquid Airlocks") and surface mirrors to redirect the view.

NOTE: The editor has been well-received by astronomy club audiences over the years for his talk on how future settlers will pursue their amateur astronomy hobby.He has also stressed that through human presence, we will over time learn much more about the planets and moons. **< MMM >**

STARDATE "440,424

By Peter Kokh

Last month in MMM #19, we discussed a Calendar for Mars. Some of you may wonder about the confusion that might arise with a profusion of special local calendars for the Moon, Mars, and each occupied asteroid and astroberg. Clearly there should be some standard or system-wide system for business persons and dispatchers, news people, historians and the like, to keep track of dates.

Of course, the time honored calendar of Earth (now rendered in CE or "common era" dates equivalent to the culturally restrictive AD or "anno domini" notation) stands ready for this, and will gather plenty of support. But let us suppose the settlers of various new worlds and worldlets are jealous of their cultural independence and refuse to go along with this terrestrial chauvinism? What neutral alternatives are there?

One unique, not world-partial idea would be to use the orbital period of the Solar System's most famous periodic comet, Halley's, or some fraction of it. This option might be seen as especially attractive since Halley's Comet visits the inner and outer system alike. But for the same reason, and its occasional approaches near enough to Jupiter to alter Halley's orbit. Its period is not a cut-and-dried 76 years, but can vary as much as three years in length, so unfortunately, that won't do.

A better argument can be made for using the 11.86 year orbital period of Jupiter since fully three quarters of the angular momentum of the entire Solar System, Sun included, lies in the motion of the big planet - Jupiter *is* the natural time keeper of our system! Divided by twelve, this would yield periods of 361.05 standard Earth days, not a bad measure at all! Such Jovennia (or whatever they might be dubbed) could be calibrated by Jupiter's perihelions (last, July 10, 1987; next, May 20, 1999.) But this just adds one more calendar (likely shared by any out-posts on the Galilean moons) to the jumble.

What we need is a dating system that doesn't pick some method for measuring out year-like or month-like periods at all, but simply marks time in an uninterrupted and continuous *non-cyclical* fashion. Fortunately, we don't have to start from scratch.

The Julian Date

For there is already in effect a dating system, which while it does use Earth standard days, pays no heed to months or years. It is known as "The Julian Date," the running total number of days elapsed since noon, Universal (London) Time, *January 1, 4713 B.C.!*

Why this date? It seems that this was the last time three cycles considered by the Julian Date inventor, Joseph Scaliger in 1852, lined up: 19 yr Metonic (cycle of lunar months); 28 year Solar; and, rather irrelevantly, the 15 year Roman taxation cycle.

For example, November 1, 1988 (publication date of this issue of MMM) will be 2,443,467 J.D. This dating is actually in daily use around the world by astronomers, especially those monitoring variable stars, stars whose brightness fluctuates in rhythms that vary instance to instance from mere hours to periods hundreds of days long.

A Friendly Ammendment

By a slight change in notation, the Julian Date system can be adapted to serve the needs of those plotting interplanetary departure and arrival times etc., intervals similar in length to those of long period variable stars. I suggested dropping the 2 of the 2 million and replace with a " mark (thus "443,467 for the date above.) A simple apostrophe (') indicating one million.)

Prior to dates preceded by an apostrophe, a degree sign (°) would handle dates in the 2738 year period from 4713 to 1876 BC, an apostrophe or single (') mark the million dates in the 1876 BC to 872 CE, to be followed by "dates for the next million dates which should take us all the way to 3512 CE.

"500,000 will occur in 2132 CE. The "star-date" given in the title above is for the touchdown of Apollo 11, *of course.*

By *not using* months or years, this J.D.-based stardate system will be as *calendar neutral* as possible. Each world can tend to its own table of equivalences, and everyone's interests are served.

(Note, as with the J.D. system, stardate will note fractions of a day past noon London time as just that, fractions. e.g. "446,721.36)

THE EPOCH:

"AD", "CE", or "NI"?

Our Dating System Does Not Recognize, nor Honor, the Antiquity of Human Culture

by Peter Kokh

Recently, many people have been replacing the A.D. (*anno domini*, Year of Our Lord) notation with CE (common era) as more religiously and culturally neutral as the Western Calendar continues to make advances around the globe toward virtual universality. Similarly, the B.C. (before Christ) notation is becoming BCE (before common era.)

This writer has strenuous objections to the B.C./A.D. system but on altogether different grounds that find the BCE/CE system just as objectionable.

Both dating systems give second class status to all persons/events living/ occurring before the current AD or CE era. That can only be justified on less than universally shared religious considerations.

Sure we "know" that there was a long pre-history to our human civilization. But with the present dating system, it is surreptitiously deleted from public awareness. If instead of the Stardate system described above, we take our terrestrial dating system to the stares, it would be much better to amend it to *include the entire rise of human civilization.*

Now before about 4,000 BC/BCE, we can no longer find any definite dates on which to pin a starting point. Yet in the several thousand years prior to the known founding of the first Egyptian Dynasty and the building of the first great Sumerian dawn city of Ur, human culture and civilization was nonetheless on a quiet anonymous rise *beginning about the time of the end of the last glacial age.* Here too, there are no hard and fast dates. But as the pace of reconstructive archeology and philology continues to quicken, we are bound to know far more about those misty millennia of the past *in the future* than we do today.

There is every reason, *for convenience sake, to add an integral number of millennia* to our present dates, thus preserving, for those for whom it matters, a certain Christo-callibration. You can argue for the addition of 4,000, 5,000, or perhaps 8,000 years. But it would be easiest, to simply add a full 10,000 years which would include those first stirrings at th close of the last glacial era. For example, that would make this year 11,988 - a figure which infinitely better communicates *with pride* the true age of our still rising human culture.

What to call this new integral era? Gone will be BC & AD, BCE & CE. We could call it P.G. for post-glacial as actually, we are in one of a series of *inter*glacial eras. But which interglacial period? Why not name our interglacial period after some prominent geographical feature that did not exist prior to this time and which will not likely survive it, such as the famous *Niagara Falls* between Lakes Erie and Ontario?

N.I. - The "Niagara Interglacial"

So I propose that, *for those of us starbound,* December 31, 2000 AD should be followed by January 1, **12,OOO N.I**. (or '2001 N.I., the apostrophe making the switch more palatable for those whose historical horizons are too encumbered to allow seeing it as a change for the better.) N.I. would be read "Niagara Interglacial."

Thus we'd be stating the thirteenth millennium, not the third.

The N.I. would set the human advance in the context of Earth's geological metahistory, to which the present system has no reference at all. BC/BCE dates from the previous 10,000 years would be rendered in the positive, and calculated by subtracting the old dates from 10,001 (for there was no year zero.) For example, the traditional date for the founding of Rome in 753 BC would become 9248 NI (yes, *that late* in the rise of human culture and civilization.)

We should carry the epic whole of our significant history with us, to the stars!

Such a system would make us all more aware of our tremendous responsibility to our forbearers not to wreck everything, by either environmental irresponsibility or by some really unforgivable Armageddon: *a permanent solution for some temporary geopolitical problem.* It wouldn't be just two millennia of progress we are trashing, more like twelve! - PK 10/**11988**

STATION MATE

Freedom's shortcomings create opportunities for entrepreneurs

by Peter Kokh

We in the space movement have sometimes been slow to learn new tricks. It took years of bemoaning the budget-mandated replacement of the originally planned fly-back piloted Space Shuttle booster by a throw-away External Tank with a pair of recoverable strap-on solid rocket boosters, before we caught on. Caught on to the fact that this serious design shortcoming gave us *an entrepreneurial opening* for commercial ventures in space *that we would never have had, had things been done right in the first place.* And so we now have ETCO, External Tank Corporation headed by Tom Rogers, and an agreement by NASA, seconded by the administration, to deliver expended External Tanks to orbit (at a 2% energy cost) for retrofitting for a variety of second-life assignments.

Recently, many of us [self included] have been extremely unhappy with NASA's current plans for the US/Allied Space Station, and with the unquestioning support by the National Space Society for this *oversophisticated, over-engineered, preemptively expensive, yet also overly-cramped and function-restricted design.* In the past months, support for this configuration has nonetheless firmed up considerably, both in Congress and on the part of the presidential candidates. Face it! ***Freedom*** will be built, sooner or later, largely as planned. It is high time to start looking for the silver lining!

One of the great lessons of life that I credit to my mother, an amateur interior decorator at heart, is that if you are stymied by a design liability, that is a sure indication you aren't approaching the feature from the right angle! Hadn't we better reexamine some of these extremely serious flaws in the NASA plan to see if they aren't also blessings in disguise for the would-be entrepreneur?

Giving us all a lesson in "how to avoid frustration and be fruitful," Space Studies Institute conducted a Lunar Systems Workshop this year. Its goal: "to create one or more scenarios or business plans for the productive use of lunar materials," guided by the "philosophy that independent, profit-making space businesses could provide a robust, non-reversible course into space." Workshop participants were divided into teams. The ideas of those on the team working on profit-making opportunities in the low-Earth-orbit (LEO) node are our topic.

This team looked for functions that our expensive but embarrassingly impotent Space Station will not be able to serve. Among the entrepreneurial niches identified:

Early markets

- storage space for experiments and equipment for the Station
- a waste management facility
- a volatiles storage facility

Later markets

- storage of cryogenic fuels (liquid hydrogen and liquid oxygen) scavenged from expended External Tanks, and next
- a refueling depot for orbital transfer and orbital maneuvering vehicles

Still later markets

- a payload rescue capability
- volume rentals
- mating of payloads and stages bound for higher orbit
- training for commercial customers

Freedom as planned well be able to provide adequately for *none* of these things.

A low-Earth-orbit services complex

That suits the SSI LEO team just fine! They propose a low-Earth-orbit services complex to fly in formation with Freedom in its 28.5° inclined orbit tot provide it with warehousing and housekeeping and the other desirable services mentioned. This complex, would be built in three stages to meet the early and later market needs outlined. It would be constructed using off-the-shelf hardware such as External Tanks, space station logistics nodules, SpaceHab modules, and if available, ACCs, Aft Cargo Carrier pods designed for bulk payloads riding up to orbit on the bottom of the External Tank. After the homework was done on the cost of delivered hardware and crew for each phase of the complex, happily, there appeared to be every likelihood that a quick turnaround profit could be made from investment for each stage, providing funding for the subsequent step.

Included in its first early phase:

- a single man-tended External Tank with various orbital modifications
- micrometeorite shield / docking adapter
- a space station logistics module
- a 25 kw power system / 2 teleoperators

This hardware, including one shuttle launch is costed at $185 M and should be able to earn $112 M/year from

- garbage/waste disposal
- equipment storage / volatiles storage
- payload attachment services
- ELV fetching
- surplus power supplied
- a large tended long duration exposure facility

If the SSI team's service pricing is on the mark, this is certainly a short enough pay-back time to entice the most venture-shy capitalist!

In the next phase, the commercial service complex would become manned full-time with the addition of a 2nd modified External Tank, logistics module, and power supply and joined by a manned "scavenger vehicle" at a total additional cost estimated at $320 M including insurance and delivery. But now the income producing potential skyrockets to over a billion dollars a year, based on the ability of the complex to outfit four external tanks a year for other customers.

In the final phase, a cryogenic storage depot would be added, requiring a 3rd External Tank tethered below the main complex to hold reliquified fuels. The aim of this depot is to enable refueling of reusable orbital transfer vehicles, including support of a Moon-return delivery system. According to the team's analysis, a total investment of $770 M 1988 dollars could lead to a yearly profit exceeding $1 billion. There seems to be enough daylight here to allow the infamous Mr. Murphy to escalate costs and deflate income and still come out ahead. At any rate, this study is encouraging.

This LEO NODE would provide *at off-the-shelf-technology prices, the services and capacities lopped off the scaled-back high tech Station.* The real prize is that *the needed services would be supplied by free enterprise*, thus opening up today's tightly closed space frontier.

It will not be easy. The first ET has yet to be delivered to orbit, yet to be refitted for the first time. Here we labor under some handicaps it would be to our advantage not to accept. In a conversation I had with Alex Gimarc, author of SSI's External Tank Study, last year in Pittsburgh, he stated his belief that the route of on-the-ground prior modifications to the ET are not worth the tremendous hassle of subsequent requalification. This may be true, *if* we are speaking of a unique set of modifications for each ET.

However, a couple of generically useful modifications might be more than worth the trouble. One is qualification of a system of prior partitioning of the liquid hydrogen tank interior into walls and floors-to-be made of aluminum grating, through which the fuel would flow unimpeded. Another is qualification of an alternative inspection hatch using a pair of counter-turning hand wheels to throw an array of radial deadbolts much like a bank vault safe, in lieu of the present hatch which requires manual removal of 98 (count 'em!) bolts. Even though simulations in NASA's neutral buoyancy tank shows that this task can be accomplished by a suited astronaut in free fall before exertion sets in, it amounts to a needless hazing ritual for commercial pledges to the government monopoly space fraternity.

With few exceptions, most of today's space entrepreneurs are trying to reinvent the axle. They have our admiration and vivid interest. What is really needed are entrepreneurs to get into payload maximizing and service-deficiency makeup areas. There is as much if not more room in these areas for a quantum leap improvement in our access to space. Three cheers for the SSI LEO NODE team*! Now let's see them sell their ideas to someone with pockets. For our part lets us all waste less time moaning, and instead seek out the advantages in NASA's design contractions.

[Cf. **First Steps to Lunar Manufacturing: Results of the 1988 Space Studies Institute Lunar Systems Workshop** by Greg Maryniak, Exec. Vice Pres., Space Studies Inst. The full report is available for $10 from SSI, P0 Box 82, Princeton, NJ 08542.]

*The LEO NODE group consisted of Faye Bailiff (Martin Marietta), Dana Andrews (Boeing), Major Alex Gimarc (USAF), Gordon Woodcock (Boeing), Peter Diamandis (M.I.T.)

CERAMIC CITY

by PeterKokh

There are several building materials options for lunar based industry. Among likely candidates for early demonstration are lunar concrete (one part in 224 [per T.D. Lin] represents the hydrogen content of water and will probably have to be upported at great expense,) lunar glass-glass composites, sintered iron, and cast basalt and ceramics. It is this last ceramic option, about which the greatest amount of disinformation exists, some of it in bad faith, the rest simply inexcusable.

A recent book “Space Resources: Breaking the Bonds of Earth” by John S. and Ruth A. Lewis is a case in point. In it, the prospects for lunar development are dismissed with the flippant “what does one do with [brittle] basalt bricks, is a neat question, one that we have been unable to answer.” Unfortunately, this book, and this section in particular, received a critically unquestioning review in a recent issue of <u>Spacelines</u>, unintentionally helping to spread the disinformation further.

Enter Nader Khalili, an Iranian with a vision, living in this country, and working around the world. The man is driven by a desire to provide low-, or even no-cost housing for the world’s teeming billions. Familiar with Iranian adobe structures, to which there is some resemb-lance by the far less developed adobe arch-itecture of the American Southwest, he has concentrated on clay and adobe building shapes and styles that lend themselves to being fired and glazed from within to form far stronger, more durable structures than the original unfired ones. His word for this is *Geltaftan* from the Iranian (Persian or Farsi) for “fired structure.” His vision then, is a home for everyman, not erected of costly building materials, but fashioned from the native soil of his homesite, *in situ* [in place, on location.]

Khalili has gone beyond this, how-ever, to experiment with ceramic sidewalks, retaining walls, underground storage tanks, irrigation ditches, etc. all dug/formed on the spot, then fired and glazed. His vision extends to stabil-sizing eroding cliffs and advancing sand dunes by firing them, to fashioning building slabs and other elements from molten lava fresh from active volcanoes, *and to the Moon.*

Invited to deliver a paper at the October 1984 symposium Lunar Bases & Space Activities of the 21st Century organized by NASA Johnson and held at the National Academy of Sciences in Washington, DC, his remarks were greeted with enthusiasm by the unsuspecting audience of “experts.”

Let us fast forward in his eyes to, say, 2020 and read the following letter from a pioneer.

Dear Mom and Dad,

How goes it down there amongst the green hills of Earth? Things are really picking up for me here up grayside.

Today (it’s sunrise here on what we optimistically call the “Garden Coast” of Mare Crisium) I began work for Geltaftan-Luna, the settler-owned construction company that is building Port Tanstaafl. At sunrise the company yards came to life as actual construction work depends on concentrated solar energy. During the preceding fourteen days of darkness, workers put together the forms and molds we will use, sifted lunar soil, overhauled machinery, and did other non energy intensive work in preparation for the nest two weeks of busy city-building now upon us.

At dawn, the great mold-wheels of assorted diameters and depths were filled with the first of their carefully measured portions of sifted lunar soil. (That’s my job - a bit humble, but it’s a start!) Then the great solar furnaces come to life concentrating the fire of untamed sunshine and directing it through a heliostat onto the soil charge in the bottom of the mold-wheels. As the charge melts (mare soil, being basaltic, has a very low viscosity and flows freely) and the mold-wheel begins to spin, the born-again magma flow easily over the reinforcing fiberglass mattes (made of nearby highland soil with a 360° F higher melting point) and around the carefully designed and precisely placed plugs that will be openings for doorways, indirect skylights (to be fitted with sun-following heliostats) and even for periscopic picture windows. These openings owe an inspirational debt to the wind-catchers built into ancient Iranian adobe buildings.

The mold-wheels are precision shaped to have a parabolic catenary curve and the resulting fiberglass reinforced cast basalt domes will have maximum strength in compression (from the soil overburden in case of habitat decompression) and tension (from excess air pressure within, not quite wholly compensated by the weight of the soil backfilled above.) The domes have a reinforced inner lip to securely anchor the floors which are fused in place one the domes are erected on their sites.

After the domes and floors have cooled down, the interiors are given a *"sodium glaze" closely related to the salt glazing commonly practiced on Earth. The glaze is applied under high heat with first pressurization so that it is really forced into every last pore to make the structure quite airtight. Moldings for hanging pictures or some of those pretty fiberglass tapestries are already built in - you don't dare try to make a nail hole! Some settlers put a sort of lime whitewash over the glaze. Others like the slightly browned (from the sodium) gray tones as they are.*

Just as lathe workers learned long ago to produce more than simple turnings, Geltaftan\-Luna has some very sophisticated mold wheels that turn out tunnel and conduit sections, vaults and apses, and other more complex elements of the modular city-structure. We also make elements that are not turned such as paving slabs, watertight plant bed-bottoms for the farms, shade walls for waste heat radiators etc. And we fuse soil outside all the entrances and airlocks to minimize troublesome soil hitchhiking a rid inside on wheels and boots. While the swiftly multiplying Geltaftan Cooperatives on Earth use basically low-tech methods, here on the Moon, it is all appropriately high-tech or at least precision work. It has to be so, as our environment is mercilessly unforgiving.

The great mold-wheels, are, of course, mobile, advancing with the edge of city construction. But some units are built to move rather quickly, for use outside the city. Next sunth, I get to go out into the field. We will begin constructing a new terminal complex for the spaceport, some thirty miles away, out farther on the mare. Fusing of the new reinforced landing pads was completed last sunth.

In case you wondered how the domes can fit together to make larger structures and the city as a whole, suffice it to say that they best lend themselves to groupings based on a hexagonal grid or honeycomb.Of course this pattern is broken by streets (pressurized, naturally) and cuniculars (pressurized pedestrian walkways or alleys.) Actually, this method of building has a whole consistent language of expression so to speak, and you'd be amazed that he variety of designs Geltaftan-Luna architects have come up with to make the city anything but predictable and boring! Yes, magmatecture, as we call it, is transforming our little corner of the Moon, all from on-site materials, with the result that the city looks (it is!) home-grown, as if it truly belongs here, almost as a native life-form.

By the way, I am studying Lunar Architecture [LunArch 101, to be exact, as a part time student at U of L. It is really a fascinating and exciting new field, and I feel my future here is wide open.

My Marimba lessons are going well. Did you know that the ceramic tubes used in the Marimbas are made by Geltaftan employees in their spare time? This kind of experimental art and craft enterprise is encouraged by the management, and they will even get you whatever tools you need.

Well, Mom and Dad, its been nice chatting but I've got to get to work. I'll write again soon,

Love,

Graham

Look for the next pair of installments of

Moon Miners' Manifesto Classics

years 3 & 4, respectively

in January 2005

For Information

on how to Subscribe to MMM either as an individual or through a group go to

www.MoonMinersManifesto.com

The EDITOR wishes to thank

Joe Bentley

for his enormous help in keying in many articles from issues 2-20 which had previously only existed in typewritten and printed copy or on Commodore 64 floppy disks that were no longer readable.