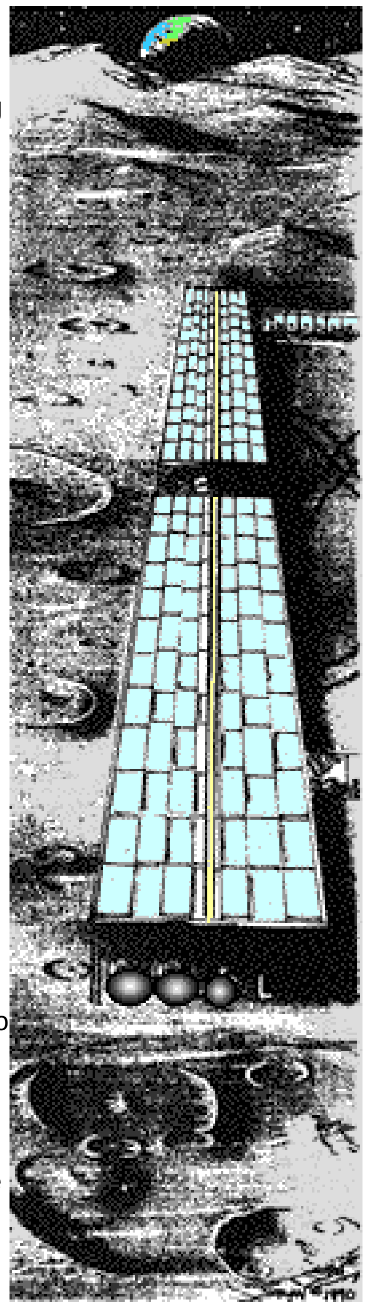
EXPANDING THE HUMAN ECONOMY THROUGH OFF-PLANET RESOURCES

MOON MINERS' MANIFESTO

MMM Classics
The First Ten Years

Year 4: MMM #s 31-40
December 1989 - November 1990



At left: **a "Ramada"**

Ramada (Ra•MAH•da): Spanish, a free-standing canopy providing shade from the sun, common in U.S. southwest.(cf. *Ramada Inn*)

Illustration © 1990, Milwaukee artist Dan Moynahan, an (M)LRS member in those days.

Vacuum is one thing; the nuisances of cosmic weather are another: intense dayspan heat, cosmic rays, solar flares, and micrometeorites. If we provided shelter from the "elements" but without pressurization - for most routine-access storage areas, and for access to the exterior areas of pressurized modules for routine servicing, would those involved in activities "sheltered" in this way be able to wear lighter-weight, more comfortable pressure suits? If so, would this reduce exertion and enhance productivity? See p. 42

The MMM Classics Effort

We have embarked on an effort to re-edit, re-illustrate and republish the major articles from Moon Miners' Manifesto issues #s 1-100 - *the first ten years.* Each volume includes the articles from the ten issues of one year.

Volume 4 concludes the hardest part of the effort, as the articles from the first four years did not previously exist in usable computer files.

Conclusion of Prinzton Rille Settlement Series

In this volume we finish up the serialization in MMM of our design study paper presented at ISDC 1991 in San Antonio.

Environmental Topics

1990 saw Earth Day #20, and as a committed environmentalist (home planet lover) and resolute space anthusiast, we published a suite of articles this year touching on some environmental aspects of opening up the space and lunar frontiers:

Star*bound

In this volume, we also begin our Star*bound series of articles, looking not at the "how" of interstellar travel, but at the "where to."

We start by taking a look from the outside, at where we are starting from: Earth and our "home star," the Sun.

MMM #31 - December 1989

Capital "M" for Moon

by Peter Kokh

A recent letter in ***Ad Astra*** [October 1989] taking exception to this writer's insistence that "Moon" be capitalized, rested on several all too common misconceptions. Perhaps it would be helpful to discuss the salient facts.

Like the Moon, Julius Caesar is an original.

First, *from time immemorial* up until 1610 when Galileo first trained a telescope upon Jupiter and discovered it had four "moons", *only one moon* was known to mankind. Similarly, until even more recent times when it became apparent that the Sun and the stars were members of the same class of celestial objects, we knew of only one "Sun". Until these recent discoveries, Moon and Sun had perhaps *never* been used in the plural. In one language version or another, since the dawn of language, *these were their names*. When we suddenly needed "class" names we *borrowed* these names from the sole objects we had ever known of each class. Ganymede, Titan, Phobos and company are thus "moons" *only* and simply by analogy or by extension. *The* Moon remains the original, the satellite of Earth.

Certainly, in such a phrase as "the innermost moon of Mars", "moon" is a common noun. But it is transparent nonsense to say that even when referring to the *original and privileged bearer* of that appellation, "Moon" is a common noun. It would be just as silly to insist that since there have been dozens of caesars (and kaisers and czars, all the same word) besides Julius, we should decapitalize Julius' surname. Like the Moon, Julius Caesar is an original.

Nor, as some are tempted to think, does the presence of the definite article "the" mean that "Moon" must be a common noun. If so we had best use the bahamas, the philippines, and the hague.

"Luna" is simply "Moon" in another language (Latin)

It has been an unfortunate common gripe among science-fiction authors (spread thereby to uncritical readers) that "the Moon" is at best an informal and colloquial name, and that it should be replaced by "Luna". While overdue international standardization of its name is certainly a worthy goal, "Luna" is simply "Moon" in another language (Latin).

Most importantly, contrary to popular belief, there is no such thing (and never has been) as "correct English." There are only judgment calls as to what is most widely "accepted" and thus "standard" usage, something subject to change. All reputable dictionaries contain a disclaimer to that effect. Living languages are continually changing *because* they are alive and *ever regenerated* by their speakers.

We are already seeing a strong movement from "the earth" to "the Earth" and indeed to simply "Earth" i.e. no "the". This evolution reflects the growing popular awareness of our planet *as* a planet. Similarly, there is increased, though less pervasive, awareness that the contemptibly familiar apparition in the night sky (the moon) is in truth another world-to-be (the Moon) upon which to continue the human drama. Newspaper editors and those English teachers wistful of the prerogatives of ancient priestly classes notwithstanding, the growing frequency with which "Moon" is capitalized expresses this new appreciation of the dawning "world" potential of the old queen of night. We might go so far as to predict that *in time*, just as "Earth" is now doing, "Moon" will shed the archaic "the".

While some may shrink in abject horror at the idea of such linguistic activism, there is certainly nothing reprehensible about trying to guide inevitable linguistic change to suit the purposes of those seeking to better express themselves. Language is a tool, and we, not it, must be master. If we, as space advocates, *want* the public to become truly conscious of the Moon as a new world for realizing the human potential, we *ought* to take the lead in capitalizing its name, even daring to drop the "the."

Ultimately, this question will be decided once and for all by the first lunar settlement government to arise. Just as most of us have learned to say Sri Lanka instead of Ceylon, if such a government decides our neighbor world should henceforth be known as Luna, Selene, Artemis, Diana, or [good grief!] Kennedy, we'll all fall into line. **<MMM>**

SPACE Space Debris DEBRIS:

Cleanup & Prevention

Editorial by Peter Kokh

Divide, and ye shall conquer!

The long awaited second part of the report The Nature of Space Debris & How to clean it up by Dr. Larry P. Lehman and Dr. Gay E. Canough of ExtraTerrestrial Materials Inc. has at last been published in the September/October issue of SSI Update High Frontier Newsletter sent bimonthly to those donating $25/year to Space Studies Institute, P.O. Box 82, Princeton NJ 08542.

The authors argue for concentrating our approach on those larger derelicts (the eventual source bodies of the more troublesome smaller fragments) that orbit at altitudes below 700 km (430 mi) where they are subject to enough drag from the tenuous wisps of the upper atmosphere that their orbits decay within a few years. The best approach would be to greatly increase their crosssection, and hence susceptibility to drag, by sending up "Small Dumb Debris Collectors" to rendezvous with them. These SDDCs would be simple sail-like devices that would open to engulf the derelict body. Orbital decay would then be greatly accelerated, and with it, the opportunity to generate further swarms of debris fragments would be proportionately reduced.

While such a plan would certainly work to ameliorate the situation if nothing else were ever to be launched (except debris collectors), we should be aware that a potentially even more troublesome class of objects could be addressed still more simply i.e. space-craft and payloads yet to be designed, built, and launched. Just to remove X percent of OLD debris per year while continuing to allow X+ percent of NEW debris-siring objects to accumulate in orbit yearly, would be a lost cause. Accelerating the orbital decay of potential debris parent bodies must be accompanied first by a well-thought out plan to make this happen automatically, second by a plan to make launched objects easier to retrieve.

We propose that the National Space Society refinem and strongly advocate the following international conventions to govern future objects bound for low Earth orbits.

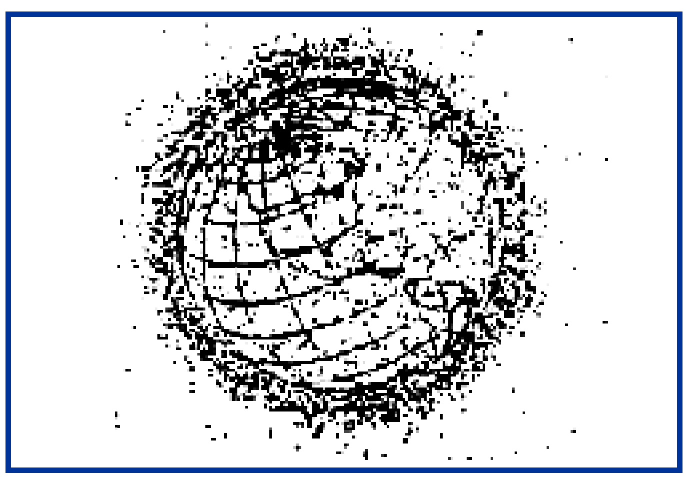
1 Farings and payload shrouds must be so designed to remain attached to the host booster and must incorporate sail-like devices that will automatically deploy to accelerate atmospheric drag on such boosters so that their orbits decay in six months to a year.

2 All payload satellites bound for drag-governed low Earth orbits (below 700 km) and not intended for intact recovery, must be equipped with a "dead-man's drag" folded sail device that will automatically deploy if power is lost, and which can be tele-deployed by ground controllers in other kinds of craft failure.

3 All orbit-bound payloads of a certain threshold size and weight must incorporate an internationally standardized grappling coupling.

4 (Any orbiting payload or craft will be declared derelict by an International Board (after admission by its launch agency or after failure of same to regain effective ground control within a two month's period) and if not retrieved or decay-accelerated by its owner or agent within a six month period, will be open to salvage of opportunity by any agent.

Space debris, already orders of magnitude more threatening than the natural micrometeorite population [SSI/ETM paper referred to above], if shunted to the background of concern by apathy, has the potential to quarantine our species on our home planet. If we fail to rise to the challenge, we will deserve that fate. *Against any disease, and that's what space debris is, prevention is the first line of defense.* **<PK>**



SPACE DEBRIS in NEAR EARTH ENVIRONMENT: May 1988.- Courtesy Nicholas Johnson Teledyne, Engineering.

"GREEN EARTH, CLEAN MOON" PHILOSOPHY TO BREAK OUT OF CRADLES BY

Peter Kokh

It is hardly possibly to turn on a TV or radio these days with out hearing about some needless environmental disaster or another instance of criminal toxic waste dumping. As if the devil-take-the-hindmost side of American business were not enough, we are all becoming painfully aware of our own unintentional guilt in passing on to our children an Earth less green, atmosphere less fresh, water less pure, forests less vast, and wildlife less abundant than those we had inherited.

It is understandable that many of us are beginning to think of humanity as a cancer upon the good Earth. Greenpeace, an extremely active international environmental group, is lobbying to set aside all Antarctica as a World Natural Preserve, banning even scientific bases as an infringement. Give Greenpeace a time-machine and its warriors would go back ten thousand years to prevent the first Siberian Indians-to-be from crossing the Bering Strait (or isthmus back then) so the Americas could remain unspoiled wilderness. Perhaps if they could go back further, they would have stood guard in the Sinai to limit mankind's ravages to Africa.

Both the trouble with this attitude, and the very real trouble that humankind poses for the environment, are grounded in the same 2000-year-old unquestioned acceptance of the premise that mankind and nature are opposed. Rather we are part of nature, a new part, a part that appears as Earth-life enters puberty. Indeed, Earth-life as a whole, or Gaia as it is now coming to be called, cannot reproduce itself, scatter its seed to worlds beyond its cocoon of space, without humanity. To reproduce, Gaia must undergo the anxious pubescent changes and adolescent tribulations that being-with-humanity brings with it. By the same token, it is not humanity that will go to the Moon, Mars, and beyond, it is Earth-life-including-humanity.

Quite frequently one hears the objec-tion, why should we go back to the Moon? Isn't polluting one world enough? The legitimate disgust the speaker feels for what is going on here on Earth is being transferred to the speaker's expectation of what must supposedly follow in space.

Mankind will not change. As our reputed ancestors cannot be housebroken, it seems that we cannot be planetbroken. We are fated to go on fouling out nest forever.'

It is impossible to argue with pessimism, because pessimism, like optimism, is grounded in temperament rather than reason. To those who wish to take the meliorist alternative, - acceptance of the given as bad as it is with the determination to take it upwards from here - there is not only hope that we will change and are changing our act here on Earth - with painful and halting steps, yes - but it is also clear that the *"oppottunity" to foul our own nest* will not follow us beyond our home planet!

Whether our stripes change or not, there are no forests on the Moon to cut, no air to poison, no groundwater or streams to pollute, no wildlife to drive to extinction. We are a danger to biospheres, yes. But there is no biosphere on the Moon, nor Mars, nor anywhere else in the Solar System within our reach.

To live on the Moon, we must on the contrary bring mini-biospheres of Earth-life with us. But whereas on Earth we can do our mischief and not worry about the consequences till much later, the tiny islands of life we bring to the Moon and Mars will be far less forgiving. We sin against them, we pay the price pronto.

It becomes obvious that Lunar and Martian pioneers will have had to change their act under sentence of death. Not only will they have to live clean, work clean, and play clean, but they will, especially on the Moon, have to recycle totally (read 100%) all the things we are used to throwing away on Earth. It isn't that they will lack places to throw things. Rather, the hydrogen, carbon, and nitrogen that largely make up wood, paper, plastics, and synthetics are not easy to come by on the Moon and may have to be imported at very high expense. Everything thrown away must be subtracted from the standard of living. Indeed, pioneers will use precious little of such materials to begin with.

In learning to thrive on the Moon, hopefully before we go, we will learn many lessons and some valuable know-how that will help us improve things here on Earth. While the motivation to clean up our act on Earth is weak but growing, on the space frontier, it will be do-or-die.

What about mining? Won't we scar the 'magnificent desolation' of the Lunar landscape? In truth, all the resources on the Moon are already lying loose in the regolith, the pre-pulverized and ready-to-scoop-up-and-process upper few yards of its surface. There is no need to either strip mine or deep mine or otherwise change the appearance of the surface. The eon-long processes that worked on Earth to concentrate ores in isolated veins and strata did not operate on the Moon. Yes, we can be sloppy, littering whatever does happen to be cheap. Only public care can prevent that.

To sum up, we must reject the offered dilemma of a Virgin World versus a Raped World. Our true choice is a world, once sterile, now brought to fulfillment of motherhood by Earth-life-*with*-humanity.**MMM**

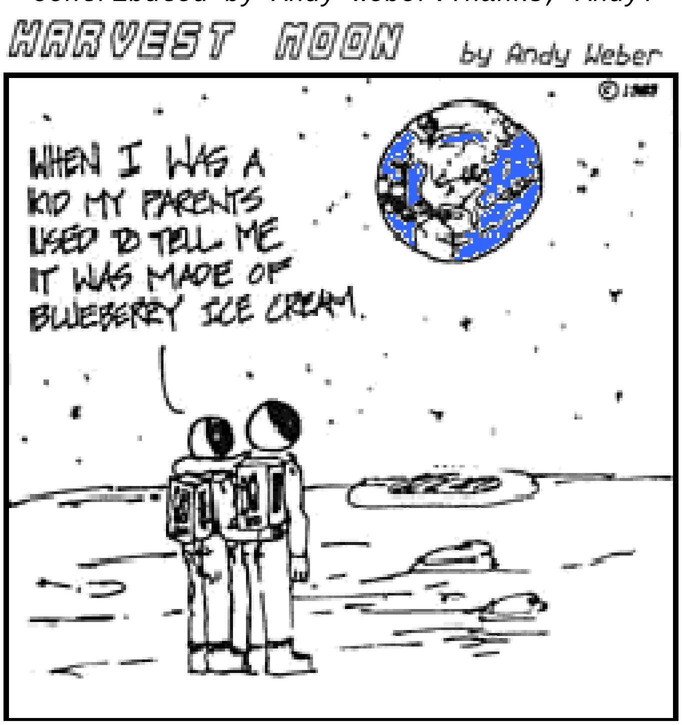
For a PDF file of the article above in flyer form, go to:

http://nsschapters.org/hub/pdf/green_clean.pdf

For more suggestions of how space activists can engage the more envrionmentally conscious persons in a constructive discussion (*not in a debate!*) **go to:**

http://nsschapters.org/hub/events.htm#enviro

*Below is **the last cartoon** of series contributed by Andy Weber. Thanks, Andy!*



MOONGLOW

by Peter Kokh

[Based in part on a Telephone Interview]

"T.L.P." - Transient Lunar Phenomena - could include any visible phenomenon on the Moon that has a fleeting existence, e.g. markings not previously seen and soon gone. in practice, however, the term is used to pigeonhole the hundreds of sightings of short-lived unusual glows, flashes, and (pink or red) colorings that have been observed by many. These happenings, however, have been seen to occur at only about two dozen sites on the Moon, a short list indeed when you consider the thousands of craters and other features covering the nearside alone. The conspicuous crater Aristarchus (brightest spot on the nearside) heads the list in the number of TLP events recorded. A distant second is Alphonsus near the center of the lunar nearside. Copernicus, Tycho, and Proclus are some of the other well known craters on this short list.

In this country there is a small but dedicated band of TLP watchful kept energized by David O. Darling, a member of the American Lunar Society and the Madison Astronomical Society. He lives in Sun Prairie, Wisconsin about ten miles NE of Madison. He became interested in TLP vigilance while observing the Moon during an "Earthshine" event in May of 1979, more than ten years ago. "Earthshine" or "ashen light" happens near the 'New Moon' when only a thin crescent is visible lit by sunshine, but the rest of the disk is visible in a dark ruddy color, the feeble reflection off the Moon's night surface from the nearly 'Full Earth' in its sky. (The Full Earth observed from the Moon is about 60 times as bright as the Full Moon appears to us!) During Dave's May '79 observation, Aristarchus began to glow so bright, you could pick the crater out with the naked eye. The phenomenon, with ups and downs, lasted about a half hour, a typical lifetime for such events. Dave has watched with dedication ever since.

About two years ago, Dave agreed to head up the TLP Watch program for the American Lunar Society. He has some 14 others in this country who regularly report to him, though some need 'encouragement'. He is looking for additional collaborators. Of greatest help are the strong ties he has established with a group that really has its act together in Great Britain, headed by Peter Foley of the British Astronomical Association. David and Peter are frequently on the phone, trading alerts, endeavoring to verify and corroborate sightings on both sides of the pond.

It doesn't pay to be on the watch for these tantalizing and mysterious events just anytime the Moon is visible, says Dave. Under full illumination by the Sun, any such color and brightness changes would simply be lost in the glare. Thought to be caused by outgassings (Radon so far is the only gas whose spectrogram has been positively identified - by the Soviets, in Alphonsus), TLP events might well occur at other times without being visually observable.

In fact, however, sightings seen to be more frequent during Earthshine (with favorable phase angles) when the Moon is also halfway between apogee and perigee (hinting that tidal stress trigger). Events also cluster at peak Sun activity (causing autgassings to glow or fluoresce).

TLP watchers gear up for lunar eclipses too. Sudden flashes sometimes occur during eclipses and may be due to electrostatic discharges from the sudden fall in temperature during the event.

As exciting as it is to experience one of these events, the real gratification comes when one's sighting is independently corroborated by others in the TLP network. Recently, Dave saw a darkening in the prominent bright ray crater Proclus (just west of Mare Crisium) and this was corroborated by several others. In the Apollo days, NASA worked closely with L.I.O.N., the Lunar International Observing Network, and a number of Earthbound TLP observations were also witnessed by Apollo astronauts in orbit on the command modules. The astronauts also reported occasional fleeting flashes as they orbited over darkened portions of the lunar farside.

The Soviet spectrographic observation is not the only instrument reading corroborating these visual sightings. The British obtained photometric (light level) verification of the ups and downs in the glow of Aristarchus during the '89 lunar total eclipse. One of the three canceled Apollo missions had been targeted to put down in Aristarchus. It would have been equipped to chemically analyze any outgassings that took place during its stay and after, for the life of the instruments. Of the three could-have-beens, this was surely the most tragic loss.

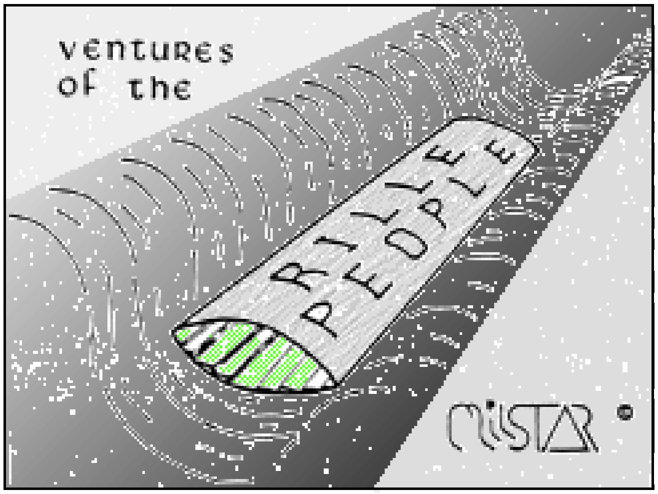
It is rather interesting to speculate whether besides radon, other more economically useful gasses might be involved, possibly bottled up in large reserves. The Moon itself is extremely poor in easily gasified volatile elements, and finds of gas reserves that had collected out of the molten magma below, and had worked their way up through crustal cracks towards the surface, could make a big difference in the pace of lunar development. Radon itself is not an original endowment, but comes from the slow radioactive decay of thorium and uranium, both of which are well represented in the lunar crust.

Even though the rocks and soil are 40-45% oxygen locked in chemical combination in various minerals, the Moon is still underoxidized. The telltale clue here is that there is much unoxidized pure iron (not ore) in the form of fine particles in the loose soil, free for the gathering with a good magnet. This could never happen on Earth. And that portion of iron which is oxidized as ore, is ferrous (one atom of oxygen to one of iron) not ferric (three atoms of oxygen to two of iron - the usual case here). Thus carbon dioxide, a major component of terrestrial volcanic gasses, is far less likely on the Moon than carbon monoxide. But economically tapable pockets of CO would be very important as a source of carbon which might otherwise have to be imported at greater expense.

Pros leave the patient and time-consuming TLP watch to amateurs, but this is not because they are disinterested. Darling keeps in touch with Dr. Cameron at U. of Colorado's Astronomy Dept. But the UC telescopes are usually booked up, unavailable for sighting confirmation.

[* Darling edits and distributes his newsletter MOONGLOW free to a short list of persons (16-17) truly dedicated to vigilant observation. Anyone interested in participating in this work can link up by contacting David O. Darling.at:
416 West Wilson St., Sun Prairie, WI 53590]

[Continuing our Report on PRINZTON - a two-tier three-village 3,000 person lunar settlement in a rille just north of the crater Prinz, NE of Aristarchus.]



Part V: MULTIPLE ENERGY SOURCES

P. Kokh, M. Kaehny, M. Mullikin,
L. Rachel, & J. Suszynski (CSSS)

A. Super Redundancy

On Earth, rare power outages serve to relieve newsfare boredom, result in some work stoppages and commuting delays, occasionally spoil frozen foods, and sometimes produce a temporary glitch in the birth rate. While electricity has long since insinuated itself into every aspect of our daily lives to the point that it can hardly be called a luxury, temporary loss is something less than cataclysmic.

On the Moon where the ambient conditions are far more severe, no matter how much attention is paid to self-adjusting thermal flywheels and biospheric ecosystems, loss of all power could quickly introduce conditions from which recovery would be difficult. Any one power system is fallible: nuclear, on site-solar, remote solar, chemical fuel cells. Redundancy is critical.

At the same time, power needs differ between the alternating periods of lunar daylight and darkness, each 14.75 days long. Some industrial operations can be polarized into energy-intensive (diurnal) and labor-intensive (nocturnal) processes. On the other hand, agriculture can thrive on the uninterrupted two-weeks of lunar sunshine, but must also have enough artificial light not to just simply survive the equally long night periods but to go on to produce an eventual harvest. It would seem that for a settlement of the size of Prinzton (3,000 plus), these minimal nocturnal food production needs for electricity will be easily much greater than the demands of industry and all other systems. In planning Prinzton therefore, we set as a design goal that each of the available power systems be sized so that in emergency, i.e. all the other systems down, it could alone meet these minimal nighttime agricultural need. At present, to our knowledge this minimum need has never been quantified. Nuclear winter scenarios have shown that a loss of 95% of normal sunshine would end in the cessation of photosynthesis. This is not quite to the point as we are talking about minimum hours of normal lighting, and not minimum sustained lighting. Therefore, we did not quantify the power needs for our proposed settlement, but left that open.

[Milwaukee Space Studies Team (MiSST), the chapter and SSI affiliate, will soon release guidelines for home basement/ garage gardeners wanting to help find such minimum lighting needs for food plants of their choice. MiSST will coordinate the results as they come in. We hope this will be a multi-year international effort.]

NUCLEAR PLANT (FISSION): Our rille sited just north of the large mare-inundated crater Prinz, contains an uncollapsed section of the original lava-tube. It is likely that the cavity it contains is some hundreds of meters in all dimensions and has a roof on the order of 40 meters thick. We believe this is a doubly handy feature. Not only does it provide a natural bridge across the rille but it is about the best conceivable spot to place a large nuclear pile. Even in the event of a runaway meltdown, there could be no danger to the nearby settlement - the hot pile need simply be left undisturbed.

Not only would such a plant be an everyday mainstay for those power needs that did not vary with the local time of the "sunth" (sunrise to sunrise, 29.5 earth days) but it would be an ideal feed for a Laser Power Tower (see below). We did not also specify a nuclear fusion plant, as it is problematic whether or not we will ever surmount the engineering obstacles to such an elusive long-prophesied power source.

ON-SITE SOLAR POWER: The site plan [MMM #28] shows three large solar array areas, feeding both the city and the mass driver export device. We left open whether these arrays would consist of advanced photovoltaic cells made from lunar materials or of solar turbines, mirrored dish/Stirling cycle systems. The latter would seem the likelier choice, barring developments unforeseen. We made no attempt to determine the amount of area needed for these solar arrays and what is shown on the site plan is no more than artistic license. The actual collector extent needed would be determined by the efficiencies of the nighttime storage system chosen to supply farming needs. The likeliest candidate would seem to be advanced fuel cells power by oxygen and hydrogen heat-cracked or electrolyzed from water reserves during the long lunar daytime by excess solar power, but also see B. below for a possibly complementary option.

[The reader is also referred to the multi-contributor discussion "Electric Options" in MMM #14 and the earlier "Powerco" in MMM #7 - See MMMC #1]

REMOTE SITE SOLAR ARRAYS: Given current long-distance power transmission technology and acceptable line losses, similar surface-based solar arrays could be emplaced some 600 km (370 mi) to the east, near the crater Lambert, which could provide a handy predawn boost in power same two days before the Prinzton sunrise. If superconducting lines manufactured from lunar materials are possible (current pessimism to the contrary), a globe-circling chain of solar power arrays, half of which would always be in the sunshine, would keep the grid powered to the brim regardless of local sun time.

Short of that, it might be feasible to place a suitably sized array 70-some degrees away just over the north pole of the Moon, say 2000 km or 1250 mi due north-then-south of Prinzton (27°N). Using non-superconducting lines such a distance would involve larger line losses then currently deemed acceptable. However, as such a site would be 180^o out of phase with Prinzton, it would enjoy sunlight for the entire Prinzton night stretch.

SOLAR POWER SATELLITES: Earth-feeding Solar Power Satellites, providing raw and processed materials for which is likely to be the economic mainstay for Prinzton, will be concentrated in geosynchronous Earth orbit, now the denizen of communications satellites. Often called the Clarke orbit after the science and science-fiction writer who first realized its strategic advantage, "GEO" allows objects to orbit in lockstep with the Earth's rotation so that they seem to be permanently parked above set points on the equator 37,000 km or 23,000 mi below.

In contrast, owing both to the Moon's low mass (1/81 Earth's) and to the slow rate of its rotation, once every 27.5 days reckoned by the stars rather than by the Sun, what would be its "Clarke Orbit" if the Earth were not present is some 120,00 km or 75,000 mi out [B.O.E.]. In fact all points this far out from the Moon in its orbital plane are within Earth's gravity well, not its own. Instead, any Solar Power Satellites intended to beam power down to the Moon will have to be placed at one of the Lagrange points where the Earth-Moon tug of war lies in precarious balance. Of these, so-called L4 and L5, some 60^o ahead and to the rear of the Moon respectively in its orbit about Earth, are the best bets, requiring little or no station keeping effort. L5 would serve the eastern flank of the Moon, L4 the western, wherein lies Prinzton. Now this L4/L5-Moon distance is some *ten times* the Earth-GEO distance. It is the feeling of J. Suszynski that power beamed in the 1 mm wavelength would be best suited given the much greater distance, and that the greater attenuation of the beam (100 times the footprint for same width beam) could be managed. The rectenna net could either be slung directly over the rille or over a nearby crater if preferred. This is as far as we carried the discussion.

B. A Hydroelectric Storage System?

M. Mullikin and P. Kokh

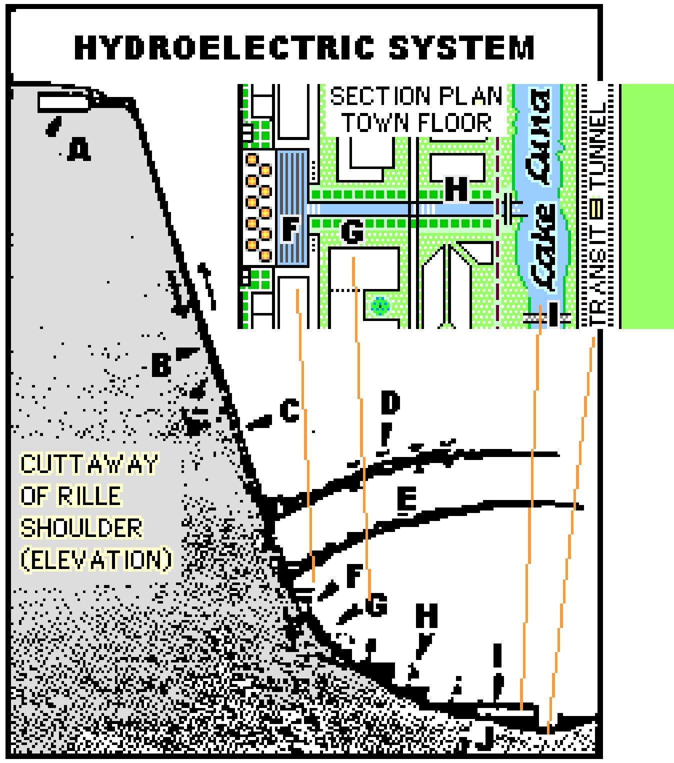
Surely, one of the most innovative ideas proposed for the Prinzton Project was Myles A. Mullikin's suggestion that we use the elevation differences within MIDVALE, the central village (whose town plan he had designed to serve as downtown for Prinzton and all this area of the Moon) to circulate water through a modest hydroelectric plant. During the day weeks when abundant solar power will be available, water reserves would be pumped from a valley bottom reservoir to one just below the lower vault, and allowed to fall through a bank of generator turbines during the two night weeks. While appreciative of the much greater power advantage to be had from electrolyzing these reserves by day to run through fuel cells by night, he was leery of the idea of storing these volatiles (hydrogen and oxygen) within the village.

Once on the table, this idea, rather than being dismissed, was quickly enhanced. The upper reservoir could be placed full-square on top of the rille shoulder. It would be no problem to pump the water up that high, and the greater head, some 400 meters, even in 1/6th gravity, would still be *effectively* half again as high as Niagara Falls! Furthermore, out on the rille-top, the water pumped up from below could circulate under quartz panels transparent to the Sun's ultraviolet fury. This would serve as both germicide and bactericide. And if still desired, water in the upper reservoir could still be electrolyzed to be recombined in fuel cells with the onset of night before beginning its fall down the conduits to the generating station below. There would be no appreciable safety risks involved.

A second set of tubes up the rille slope would carry air rushing counterflow as it is displaced by the water being pumped up or falling down as the case may be. Air pressure in the rille-top reservoir would have to be the same as in the village below. A heat-exchange system could cool hot upper reservoir air before it flowed into the village during the day time, giving up heat to the water. The whole system would act as a thermal fly wheel to give Midvale the most equable climate of the three villages.

Meanwhile, the generating station could be placed with little sacrifice in power at the top of the Town terraces, the spent water then free to work its way down a series of ponds and cascades to a central lagoon for all to enjoy. The shallow seven acre lagoon with canoes, fishermen, and pink flamingos would be cantilevered over the final reservoir with depth maintaining overflow tubes leading from one to the other. Some of the water from the Hydro station could also be shunted to pressure-fed fountains, further adding to the Metro-class character of this village. While the extra power to be gained by the hydroelectric scheme as opposed to the straightforward fuel cell system, is probably very modest given the limited volume of water probably available, it might well be proportionate to the extra lighting and energy load the twenty-four hour character of Midvale's Metro District would have, serving not only its own village population, but those in the other two villages whose work and living schedules are to be eight hours advanced or retarded. [See "Rille People" Part III B. The Three Village System. MMM # 28.- republished in MMMC #3, pp.41-43.]

HYDROELECTRIC SYSTEM: For the Central Village of Prinzton (MIDVALE).



[**A**] Upper Reservoir includes quartz pane covered purification pond (Solar Ultra-violet in). Option would include tanks to hold liquid oxygen and liquid hydrogen electolyzed from water, and fuel cell power plant for recombining them.

[**B**] Slope of rille. [**C**] Tubes or conduits carrying water and counterflow displacement air. Day dates: water up, air down. Night dates: water down, air up.

[**D**] (Heliostats gather and bring sunshine into) [**E**] The upper Farmfield level.

[**F**] Hydroelectric station at uppermost terrace of lower Townfield area.

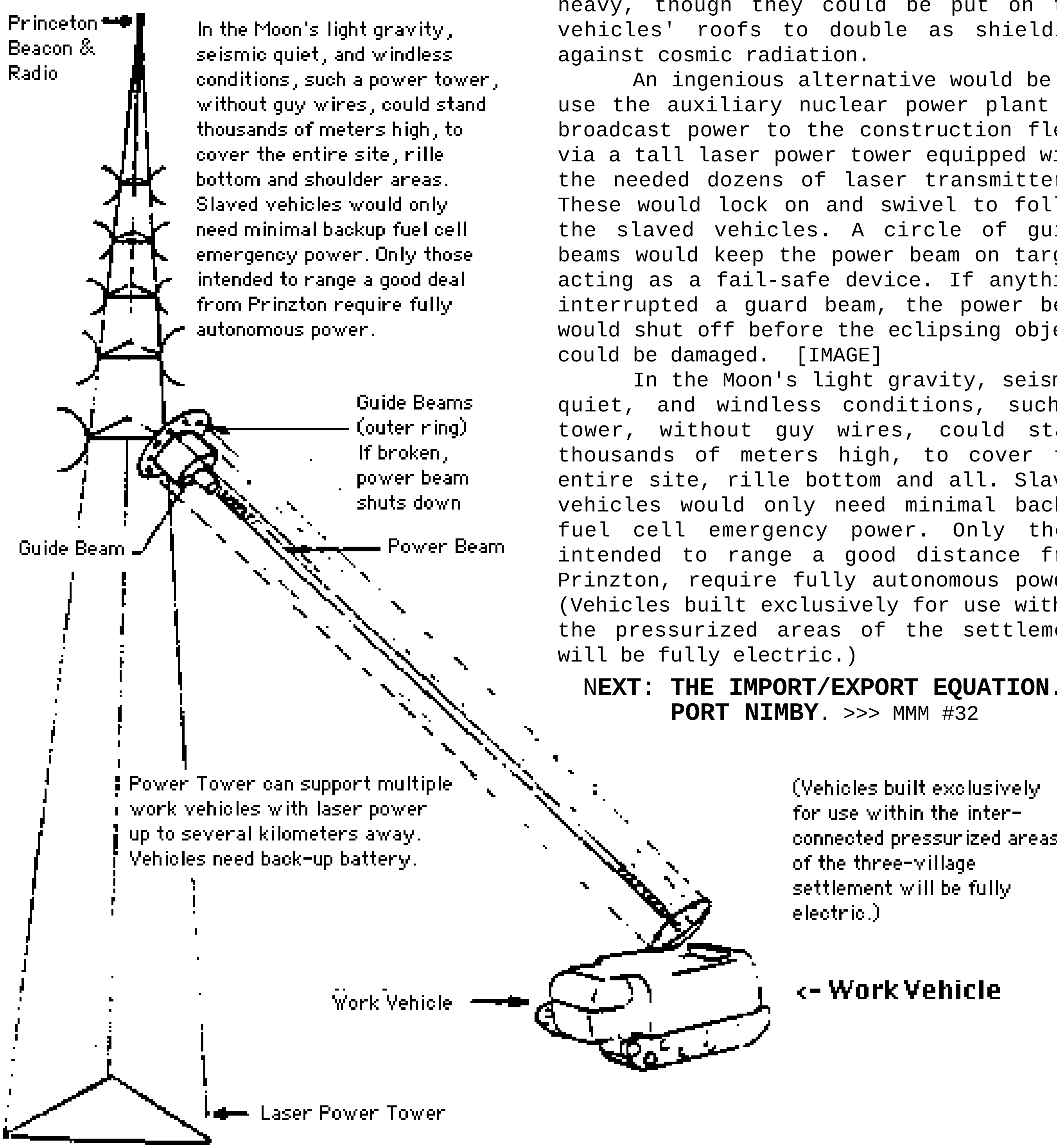
[**G**] Decorative cascades. The spent water is put to landscaping use on way to lover reservoir. [**H**] Pressure-fed fountains.

[**I**] Shallow 7 acre lagoon cantilevered over [**J**] Lower reservoir fed by overflow pipes from lagoon above. Reservoir fills during the lunar night, is pumped empty during lunar day.

Such a hydroelectric scheme uses solar power priming in a way surprisingly not so different from that we are familiar with on Earth. Here, sunshine evaporates ocean water to fall as rain and work its way down the drainage system. The Moon may be the last place you would expect to find a niche for hydroelectric power, but it will work, for what it's worth. Not jist rille slopes, but lava-tubes and larger crater slopes are potential "dam" sites.

C. The Laser Power Tower

Power Tower Concept - M. Mullikin,
Power Tower illustration - D. Cremer



Building Prinzton will require a considerable fleet of construction vehicles. To power these with petrochemical fuels is out of the question. Far less expensive and quite clean would be fuel cells using liquid oxygen processed from the lunar soil and hydrogen imported from Earth or, better, Phobos and Deimos. The emission is water which can flow into Prinzton's reservoirs or be resplit into hydrogen and oxygen to be used again. However, the banks of fuel cells needed would be quiet heavy, though they could be put on the vehicles' roofs to double as shielding against cosmic radiation.

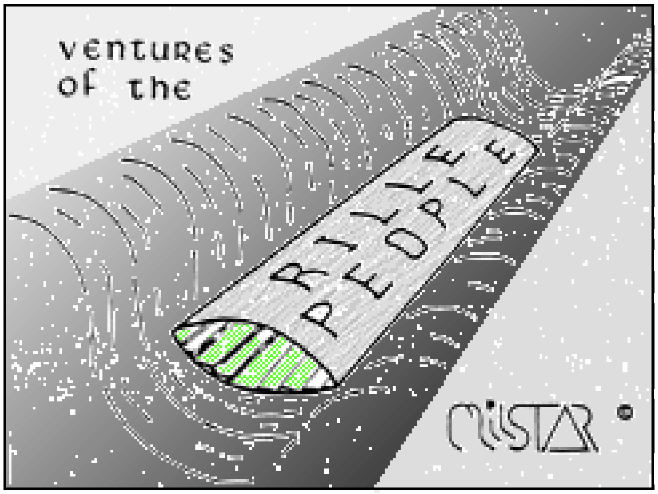
An ingenious alternative would be to use the auxiliary nuclear power plant to broadcast power to the construction fleet via a tall laser power tower equipped with the needed dozens of laser transmitters. These would lock on and swivel to follow the slaved vehicles. A circle of guide beams would keep the power beam on target acting as a fail-safe device. If anything interrupted a guard beam, the power beam would shut off before the eclipsing object could be damaged. [IMAGE]

In the Moon's light gravity, seismic quiet, and windless conditions, such a tower, without guy wires, could stand thousands of meters high, to cover the entire site, rille bottom and all. Slaved vehicles would only need minimal backup fuel cell emergency power. Only those intended to range a good distance from Prinzton, require fully autonomous power. (Vehicles built exclusively for use within the pressurized areas of the settlement will be fully electric.)

NEXT: THE IMPORT/EXPORT EQUATION. PORT NIMBY. >>> MMM #32

MMM #32 - February 1990

Continuing our Report on PRINZTON
a two-tier, three-village rille-bottom settlement for 3,000 - 5,000 persons



EXPORT/IMPORT EQUATION

IMPORT / EXPORT EQUATION

Part VI: TO SURVIVE, PRINCETON MUST EARN MORE IN EXPORTS THAN IT PAYS FOR IMPORTS

Peter Kokh

A. Settlement Import Categories And Strategies to Cut and/or Avoid Them

1. CAPITOL EQUIPMENT: “MUS/cle” co-manufacture is easily the most promising approach. A minimal sintered iron and glass composite manufacturing capacity must be imported FIRST. Thereafter, complex lightweight electronics-rich ("cle") "works packages" from Earth are mated to Massive Unitary Simple ("MUS") parts made on the Moon of Lunar materials and assembled on the site to make additional equipment for Energy Generation, Mining & Processing, Manufacturing, Construction, Fabrication & Repair, and for Food Production. [cf.: "M.U.S./C.L.E." in MMM # 18 September '88.]

2-SETTLERS: *"Bantamweights" will do.* For Prinzton will be run with brains rather than brawn. Weight savings on settlers can be applied elsewhere.

3-FARM PLANTS AND ANIMALS: Seeds only, and worms and bee colonies; Seeds packed in hot pure N₂ to kill hitchhiking pests; Unpatented non-hybrid cultivars only; and pregnant female animals only.

4-VOLATILES: Hydrogen, Carbon, Nitrogen: The import burden can be softened by some careful measures faithfully pursued:

(a) Harvesting, by heating, of the significant quantities of H, C, N, and other gases adsorbed to the fine regolith particles, thanks to eons of bombardment by the Solar Wind, during all those construction processes involving soil moving;

(b) Out-sourcing to gravity wells shallower than Earth's e.g. Phobos and Deimos, Earth-approaching asteroids and comets;

(c) Conservation of volatile-rich organic materials by religiously thorough recycling efforts. In support of this goal Prinzton will need "kosher" (organics not bonded to inorganics) knock-down- friendly ("KD") assembly methods; systematically thorough and foolproof sorting clues and handy routing managements; and above all the help of ingrained second-nature good habits and expected chore assignments.

(d) 'Pre-codesigning' of all single-use containers for volume-matched secondary more durable uses. (An example already attempted was the elusive "World Bottle" design i.e. a bottle that could be reused as a brick; Effort not yet successful.)

(e) Buttoning up pressurized areas for Nitrogen conservation by use of novel airlock systems: Matchlock “intergates” to allow suitless shirtsleeve transfer between vehicles and habitat areas; Liquid airlocks for some freight categories such as goods manufactured inside for use in vacuum and vice versa; and Turtle-back spacesuits that back into special mated airlocks for direct entry from suit to habitat and vice verse.

5-RARE METALS: An elegant way to painlessly "co-import" rare metals, and even some synthetics is by making all needed shipping containers end packaging out of such materials i.e. the easily forgotten category of "Tare". [Gross - Net = Tare] Making this standard practice could provide a tidy "cheap" endowment of badly needed materials hard to process from the Lunar soil such as copper, brass, other precious metals, other needed alloying ingredients, and even some volatiles in the form of lightly polymerized synthetics. Crates, Boxes, Barrels, Tanks, Cans, Bottles, and packing stuffing and dividers could all be made of such strategic materials.

6-HABITATS: To make the Prinzton construction camp, an original minimum number of tight-packed space station module type sardine cans can be followed by locally manufactured and constructed Big Dumb Volume Structures in which are placed "Works Core Modules" made on Earth. Such cores would contain Kitchen/Bath facility, electrical service, communications-entertainment center, air conditioning-heating-cleaning unit, etcetera. The total core package would be lighter (no massive hull) and cheaper to upport from Earth and the host habitat would be much more spacious and cabin-fever resistant. Such Works Core Modules, but with an ever greater Made-on-Luna "MUS/cle" content, also serves in Prinzton's Village Homes.

7-NON SELF-MANUFACTURED GOODS: For those needed and desired items Prinztonians need but are not yet capable of providing for themselves, the "MUS/cle" formula is again part of the answer. But substituting metal, glass, Glax* [composites], and ceramics wherever possible for wood and plastics, and doing without wherever this is impractical must be Plan A. Mail order catalogs from Earth will be taboo and instead items from the hands of local artists and craftsmen will be treasured. A paperless all-electronic society will be a top priority goal. [cf: "Paper Chase", MMM # 4 April 1987, republished in MMMC #1.]

B-Strategies to Lower Import Costs and/or Increase Import Quantities

1-ALTERNATE SOURCES: Prinzton will need to import considerable quantities of hydrogen, carbon and nitrogen, most easily handled in the form of methane CH₄ and ammonia NH₃. Discounting the amortizable capital costs of emplacing the needed equipment, these volatiles can be shipped at a fraction of the total fuel cost, from Phobos or Deimos, moons of Mars, at regular 26 month intervals. Such shallower gravity well sources also include occasional catch-as-catch-can Earth-approaching asteroids, comets, and wildcat-worthy inactive comet-hulks. The Moon's deficiency is the Solar System's gain. For settlers will have a do-or-die urgency in pioneering such markets.

2-LOWERING COST-OFF-EARTH will be above all a matter of developing (at last!) more economical surface-to-orbit launch systems. But our crafty settlers will also attempt to lower prices FOB Earth by buying goods on favorable terms Solar Power Satellite customer nations.

3-LOWERING COST-ONTO-MOON. Unlike both Earth and Mars, the Moon has no handy atmosphere to allow aerobrake assistance. But there are other more inventive alternatives to full retrobraking. These may include skid-landing on prepared regolith smoothways. [*Lunar Bases and Space Activities of the 21st Century*, W.W. Mendell Ed.r, Lunar & Planetary Institute, Houston 1985 pp. 848-50 "The Lunar Slide Lander" by Kraft A. Ehricke] and the "Edportation" scheme of Chicago inventor Ed Marwick. Passengers may not line up for such wild rides, but drone "sliders" could bring in needed bulk materials and other hardy cargoes.

C-LUNAR EXPORT CATEGORIES

1-BULK MATERIALS: Liquid Oxygen; Regolith for shielding; Enriched ores for space processing.

2-OXYGEN CONTAINING PRODUCTS such as Water and Foodstuffs cheaper than from Earth even if they contain terrestrial Hydrogen and Carbon.

3-BUILDING MATERIALS AND COMPONENTS: Iron and Steel; Aluminum, Titanium, Magnesium alloy; Glass and Glass-Glass Composites; Ceramics & Concrete.

4-ITEMS MANUFACTUREDE ON THE MOON to cut imports are also marketable to LEO, GEO, L5, Mars Ph/D (Phobos, Deimos): Furniture and furnishings; Tanks, Holds, Appliance Cases, other items.

D-EXPORT DESTINATIONS

Low Earth orbit Space Stations and other manned facilities, Space Colony Oases at L4/L5 or in other orbits, and Mars-bound expeditions are all Markets for Lunar Lox, Food, Water, building materials products, and sundry finished goods all Lunar or MUS/cle assembly). Geosynchronous orbit is a destination for large multi-satellite capacity platforms and Solar Power Satellites.

E-STRATEGIES TO INCREASE EXPORTS

1-LOWERING EXPORT LAUNCH & DELIVERY COSTS: Mass Drivers, Bucket, and Pods should be upgraded to launch more profitable *value-added goods.*. 1st Upgrade: enriched beneficiated ores: Fe, FeO, TiO, Al203, CaO, MgO, SiO; Batch-loads of glass matrix, glass fiber, and cement.

Second Upgrade: right-sized ingots: Fe, Al, Ti, Mg. 3rd Upgrade: shock-proofed pods of small manufactured parts. In addition, goods bound for Earth's surface could be shipped in no-transfer self-contained Earth-aerobrake-and-Land "dynasoar" capsules.

2-INCREASlNG MARKET DEMAND:

Liquid Oxygen: Would-be-Prinztonians should push develop-ment of "Stage Plus" Earth Deep-Space Launchers designed for on-orbit LOX refueling. Food deliveries to LEO stations and other space locales, will depend on selection, delivery, marketing.

Building Materials: Lunar Owned Space Architecture and Space Construction Firms will channel a greater share of space construction profits back to the Settlement. *Promotion* of the 1/6th G lunar Gravity as a Standard for rotating space structures will mean quicker more frequent sales because the rotation rate linked minimum size and mass of such structures will be an order of magnitude smaller, a more attainable threshold.

Prinzton made Consumer Goods can be promoted along with Lunar-type material culture in general as the appropriate norm for near Earth facilities in the era of still expensive volatiles. Such goods involve material substitutions and a high profile for Art/Craft made wares.

Promotion of the Moon as the "Hub" of the ETM (extra-terrestrial materials) economy will be an essential settler policy. Their do-or-die motivation and proven know-how will drive Lunar-initiated market development of Mars and its moons, and of the Asteroids. Key here may be the development of Minimal Mobile Biospheres. The larger deep-space long-cruising vessels have to be to hold self-contained mini-biospheres, the greater the obstacle to opening the asteroids.

3-MARKET TARGETING:

Logical Earth Trading Partners for Prinzton are those nations which are at once

- Energy Importing Countries (Solar Power Satellite sales, Helium-3 sales) *and*
- Sources of elements not economically Lunar-sourceable yet strategic to Prinzton development.

Many of these countries are in the “Urban Tropics.”

4-MAXIMIZING TOURIST INCOME.

The lure to well-heeled sightseers can be intensified in several ways.

A "**Seven Wonders**" **list**, carefully drawn up and publicized, and a variety of enticing itineraries will encourage repeat trips or at least longer stays.

Special ways to taste the settler way of life can be offered to visitors.

- Stays in lunar homes
- working tours
- Art & Craft classes
- special tours e.g. of factories and recycling systems, and
- the opportunity to actually participate in unique Lunan sports.

Customs regulations can entice tourists to trade all their Earth garb (for Lunar Stage/Theater Use) in exchange for souvenir Made-on-Luna apparel.

Shopping Spree Tours for unique arts, craft, and clothing pieces at the Settlements cottage industry flea markets should be marketed.

5-TELEVISION & FILM MEDIA SALES:

Advertising Revenues could be appreciable enough to wholly finance:

- Development of Unique Lunan Spectator Sports, which in turn could be televised to Earth audiences hungry for something new and exotic.
- Construction of any facilities such sports may require
- The same goes for the "ethereal" Prinzton Ballet Company, probably awaiting the coming of age of the first native-born generation.
- Documentaries about Prinzton and Lunar activities at large will vie with space adventure films for the use of the Out Of This World film studio in Prinzton.

6-EXPORTING KNOW-HOW:

Technology transfer is a potential money-maker for Prinzton. Hopefully much of the technology needed to make Prinzton a thriving reality will have been pre-developed for profitable terrestrial applications and thus served to keep Prinzton's up front costs far lower than they otherwise could be.

But enterprising young Prinztonians will develop new products and processes saleable Greenside. **<MMM>**

DIVERSIFICATION $$$UB$$$IDIE$$$

Peter Kokh

+ EXPORTS
- IMPORTS
BOTTOM LINE

We have outlined a very ambitious picture of what a mature Prinzton economy might look like. But what is the logical order in which such a well-rounded economy might be best achieved? Diversification will in part depend on a number of things that we cannot accurately forecast at his time:

- **Size of the LEO market** for LOX, building materials, other manufactured and processed goods
- **Progress in opening up space markets elsewhere**, e.g. Phobos/Deimos etc.

Different scenarios can be plotted assuming various values for these unknowns.

We *can* list some very pertinent questions, however. Their nswers will greatly affect the strategy and game plan chosen.

For each industry proposed for Prinzton, we will want to know the following:

(1) What is the industry’s capacity to ***generate export tonnage?***

( ) Major - ( ) Medium - ( ) Minor

(2) What is the industry’s capacity to ***defray import tonnage?***

( ) Major - ( ) Medium - ( ) Minor

(3) What is the ***export value-added*** per tonne?

( ) Major - ( ) Medium - ( ) Minor

(4) To what degree is the industry ***labor-intensive***?

( ) Major - ( ) Medium - ( ) Minor

(5) To what degree is the industry ***energy-intensive***?

( ) Major - ( ) Medium - ( ) Minor

(6) What is the industry’s ***pressurized acreage need***?

( ) Major - ( ) Medium - ( ) Minor

(7) How well can the industry’s operations be separated into ***successive*** diurnal (dayspan) ***energy-intensive*** vs. nocurnal (nightspan) ***labor-intensive portions***?

( ) Major - ( ) Medium - ( ) Minor

(8) How much ***heat*** is ***needed*** for operation?

( ) Low - ( ) Medium - ( ) High

(9) How much ***heat*** is ***generated*** by operation?

( ) Low - ( ) Medium - ( ) High

(10) What is the industry’s ***need for vaccum?***

( ) Major - ( ) Medium - ( ) Minor

(11) What percentage of ***chemical reagents*** used can be ***recycled***?

( ) Major - ( ) Medium - ( ) Minor

(12 a) To what extant can the industry be ***set up in modular units*** so that production capacity can be easily increased as needed?

( ) Major - ( ) Medium - ( ) Minor

(12 b) How high is the import tonnage of each module in terms of economic gains?

( ) Major - ( ) Medium - ( ) Minor

(12 c) To what extent can **MUS/cle*** co-manufacturing savings be applied to additional modules needed? [* see the article from MMM #18 in **MMMC 2**, pp. 34-35]

( ) Major - ( ) Medium - ( ) Minor

(13) What ***prior industrial material byproducts*** are presupposed?

( ) Major - ( ) Medium - ( ) Minor

(14) What ***prior processing capacities*** are presupposed?

( ) Major - ( ) Medium - ( ) Minor

(15) What subsequent industries are e***nabled by new byproducts*** generated?

( ) Many - ( ) Few - ( ) None

(16) What subsequent industries are enabled by processing capcities offered?

( ) Many - ( ) Few - ( ) None

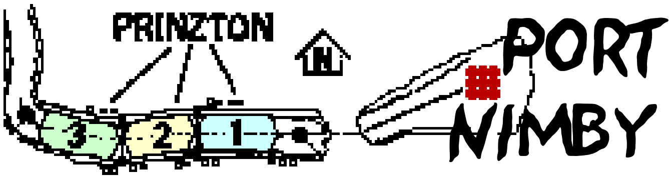
(17) How “***ready-to-go***” is the technology for operation ***in Lunar Conditions***?

( ) Little - ( ) Partly - ( ) Go!

Once we’ve done our homework
on these and similarly
relevant questions,
we will be ready to begin
a serious discussion
of long-term
Lunar Industrialization Plans

< M M M >

"**Not In My Back Yard" - "N.I.M.B.Y."**



IMPORT/EXPORT SLEEPER
Gross Imports that Could Count as Net Exports

Peter Kokh and David A.Dunlop

IMPORTING FOR DIRECT PROFITS

This may seem like a Cinderella idea. Prinzton already works toward overall net profits by putting major emphasis on importing *capital equipment* to help both lessen the need of further imports and increase exports by enabling ever more local processing and manufacturing MUS/cle (see the article from MMM #18 in MMMC2, pp. 34-35) and*co-importation* by clever choice of *tare* materials. (see previous article in this volume of MMM Classics, Diversification/Subsidies, A.5.)

Every Trade Czar's fairy tale dream, however, is to *be paid for* the imports one's people need, rather than paying for them. Simply put, this means agreeing to take something unwanted-with-desperation off the hands (and minds) of some other bailiwick. Highly Toxic Chemical Wastes, Virulent Biological Wastes, Radioactive Wastes - might all fit this description.

"**Not In My Back Yard**" - "**N.I.M.B.Y.**" - is the classic universal reaction to these leprous by-products of today's advanced technology. In recent years, the unwelcome reality that every where on Earth is someone's back yard, is slowly sinking into the public consciousness. Governments continue to search for cost-effective-yet-safe ways to store or neutralize such techno-feces but it seems to be a hopelessly intractable problem. Promising solutions emerge only to be found fraught with fatal flaws.

Perhaps we need only be patient and elegantly "safe-yet-cheap" solutions will present themselves. But perhaps not. Meanwhile, problem wastes will keep on accumulating at an alarming rate so long as we do not wish to face the fact that those desirable materials that involve such byproducts may not be worth the ultimate cost.

Space to the Rescue?

Ahah! You say. "Space to the rescue!" Several space-involving solutions to this run-away problem have been proposed.

(a) Let's move the offensive Chemical Processing and Biological Engineering Plants to LEO, low Earth orbit, where wastes can be dumped harmlessly in space. Alas, we are now learning, LEO is a very temporary place and everything parked there will eventually find a way back into the atmosphere. We must go well out, beyond the Van Alien Belts, to a realm ruled by the Solar Wind rather than by tenuous tentacles of our atmosphere. GEO, the Earth-synchronous orbit that is home to most communications and weather satellites, will do, as will the L4/L5 Earth-Moon libration points, or high-perigee Earth-Moon resonant orbits. The Solar Wind would carry offensive exhausts well beyond the outermost planets. (Heliopause smog?)

(b) "**Dump the stuff into the Sun**" seems the ultimate solution to those blissfully unmindful of common orbital mechanics facts-of-life. Of all space solutions proposed this is surely the most outrageously expensive in "Delta V" i.e. fuel expenditure requirements. First our skull-and-crossbones payload must be accelerated to some 25,000 mph just to reach the shoulder of Earth's gravity well. Then it must shed All of Earth's forward orbital speed, another 66,000 mph worth of velocity change. A short burn, short by *any* amount, would result in a highly elliptical orbit, bringing our "Flying Dutchman" alternately in towards the Sun and back out to Earth's orbit. In contrast, it would be far cheaper, in terms of fuel cost, to catapult this dreaded stuff in the other direction, out of the Solar System altogether. Another cheaper possibility would be to shoot for the all-engulfing depths of mighty Jupiter, as we hope to do with part of the Galileo probe in December, 1995.

(c) Expel it from the Solar System. An even less expensive option than feeding the Sun, Jupiter, or the interstellar dust and gas clouds, is available to some future Dreaded Wastes Authority. We could rocket our nasty stuff into simple Solar Orbit, tele-open the canisters, and let the Solar Wind provide the Delta V, gently but inexorably blowing the stuff out of the System.

"one person's trash
is another person's treasure"

Back to the drawing board

But all of the above suggestions choose to ignore the bit of wisdom that "one person's trash is another person's treasure".

All three of the problem waste categories we are discussing, *are problems because of* the over-context of Earth's Active Geology and Encompassing Biosphere.

This given geo-context renders inherently dangerous any and all methods of value recovery by incineration, distillation, electrolysis, precipitation, or whatever. Take the stuff out of this context and the entire situation has changed.

Toxicity = toxicity *to* something.

Absent one of the two terms (biosphere) and it becomes totally illegitimate to continue to call the substances in question "toxic". Now, in this changed situation, we can talk possibilities fruitfully!

The next step is to determine where these troublesome wastes might have salvage value. You guessed it! - to *settlers* on our volatiles-impoverished Moon! To illustrate the potential of this Lunar Solution, we included *Port Nimby* on the periphery of the Prinzton Settlement Site. [see map hint in title art above.]

However, our settlers could afford to pay to import such tainted volatile-rich (hydrogen, carbon, nitrogen plus extras) shipments only if they were subsidized by desperate terrestrial authorities *to the point that* they would be markedly cheaper than the alternative Phobos-Moon "pipeline", with the much greater cost *and* difficulty of clean processing of the NIMBY hot stuff. Of course, if the shipments were free, F.O.B. Port Nimby, that would be ideal. That is unlikely, however, as one could expect custodial authorities on Earth to foot the bill to toss the stuff out of Earth's gravity-well but not the additional cost of soft-landing it on the Moon. Free "F.O.B. L1", on the crest between the Earth's and the Moon's gravity wells, is about all our settlers can realistically expect.

The biosphere discontinuity (the extremely hard vacuum and the total absence of ground water) between Prinzton and Port Nimby is what makes such an option many orders of magnitude safer than the most ideal of storage-on-Earth schemes.

Storage in lava tube sections, which have to date survived intact for nearly four billion years, leaves *no rational* basis for qualms of *informed* conscience. This is *not* case of disrespect for the Moon, anymore than it would be for the Sun. Again, toxics are not disrespectful to the Earth *geo*-logically considered, but only *bio*-logically considered. That is, they disrespect *Gaia* (the new name for Earth's biosphere) *not* Earth itself. In contrast the Moon has no biosphere *whatsoever*, and the totally encapsulated mini-biospheres that we will establish there, can be *easily* kept rigorously isolated.

What's in it for the Settlement?

Much of the salvage processing of these "profitable imports" could be done robotically and/or by teleoperation from the safety of isolated bunkers.

The prizes to be gained are recovered **water** and **carbon dioxide**, and possibly **organic feedstocks** for production of those synthetics for which the settlers are not able to make inorganic substitutes, or reasonably do without,

They might also "mine" the ash for **heavy and precious metals.**

Special "designer" bacteria night be of help in the process, though the sheer variety and probable careless premixing of wastes Earthside would tend to make this impractical as a general approach.

It is possible, of course, that we will develop safe methods of detoxifying such wastes on Earth and/or quit producing them in the first place.

The point may never be reached where the lunar solution becomes economically attractive.

A lot depends on when and if transport costs come down substantially.

Radiactive Wastes

What about Highly Radioactive Wastes? This is a considerably more stubborn problem. *No* storage site on the geologically active Earth can be safe for the full length of time needed, excepting possibly the deep-*injection* of such "hot" wastes into active subduction zones, for example where the Pacific plate is slowly diving under the advancing North and South American continental plates. By the time, if ever, such dumpings reemerged up some volcanic throat after tens or hundreds of millions of years of mixing with molten magma deep below the crust, no problem would remain. *If that solution remains an impractical dream,* then the intractability of the problem could make the *lunar* option very attractive.

Mining Radioactives for power and water

But how would settlers put such shipments to use? Perhaps they could be densified by distillation into significantly hotter concentrations, useful for generating Nighttime Power. They would be reclassified from "fuel" to "waste" when the power density they support falla below a certain level economically useful for the competitive generating stations on Earth. Yet they might still yield economical power in the quite different lunar economic environment.

Any water in which these hot shipments are stored for shipment, once repurified, would be a very welcome *free* addition to the settlement reserves. Further, radioactive wastes might also come in very handy for maintaining thermal equilibrium for the settlement. And the temperatures generated might allow continued nighttime operations of some industries using concentrated solar heat by day such as glass and ceramics production and other "life-blood" enterprises.

There are a lot of ifs that we can not honestly resolve here in 1990. The realistic cost of disposing highly radioactive wastes *safely beyond a reasonable dowbt* may be so great that a lunar solution will become attractive.

But then, even if “the economics” became "right", there will be a host of public misconceptions to overcome - including the absurd pseudo-physics behind the opening “catastrophe” of the first episode of the mutch-watched science-fiction TV series, “Space 1999” in which a runaway reaction in just such a lunar repository of Earth’s radioactive wastes dislodges the Moon from its orbit around Earth, to wander through space endlessly, meeting a host of aliens along the way, of course..

But possibly such "wastes" will be the first "treasures" imported by some future Port "N.I.M.B.Y." on the Moon.

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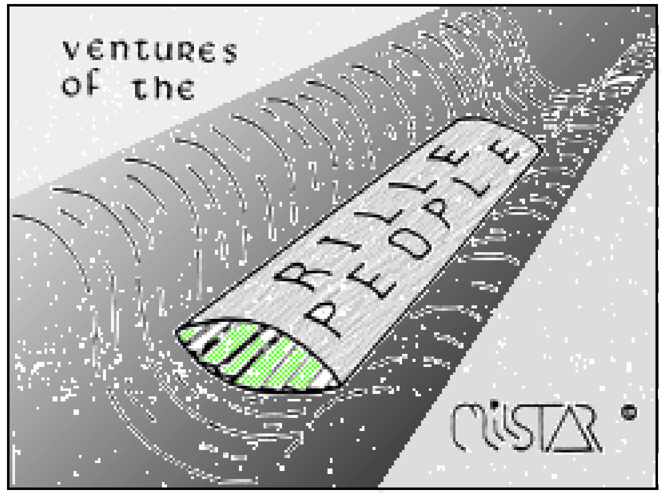
MMM #33 - March 1990

Concluding our Report on PRINZTON
a two-tier, three-village rille-bottom settlement for 3,000 - 5,000 persons



Part VII: CONCLUSION.
A. Prinzton in a Multi-Site Lunar Economy

by Peter Kokh

PRINZTON CONTRACTORS: By virtue of the manufacturing capacity *and* experience, Prinzton must possess to develop and build itself, it will have contractors able to assist in construction elsewhere on the Moon. On this list will be *know-how and equipment* to build similar rille-vault and crater-vault structures, including sky-panes and heliostats, funiculars (rille- and crater-slope elevators), regolith-moving draglines, people movers, and general biosphere set-up and maintenance capacities.

CO-MANUFACTURERS: Prinzton will also have built up facilities for “MUDS/cle” assembly of works packages made on Earth with casings made locally: appliances, vehicles, equipment, etc. After it meets its own needs, such co-manufacturing and assembly production will be available for transshipment to other lunar sites.

MANUFACTURED GOODS: As Prinzton meets its own needs, its factories can continue to turn out furniture, furnishings, and other household goods for other lunar settlements. Other items it can supply to smaller communities (mining towns, etc.) will be modular parts for utility systems, service harnesses, etc.; light vehicles, bicycles, and carts; containers and packaging; processed foods, cosmetics, and dyes; clothing; arts & crafts materials and tools; recovered volatiles and feed-stocks from Port NIMBY operations; field-tested plant seed and seedlings; agriculture and biosphere equipment.

EDUCATION: In addition to having schools more complete than smaller settlements can provide, plus a small university, Prinzton will be a source of Moon-appropriate text books & manuals and traveling instructors.

ENTERTAINMENT AND CULTURE: Not only would Prinzton be an entertainment *Mecca*, its singers, dancers, actors, and story-tellers could go on periodic tours to the various out-settlements. Prinzton would be a natural media center.

B. RILLE-SITE VARIATIONS: NATURE PRESERVES AND GET-AWAY RESORT COMPLEXES

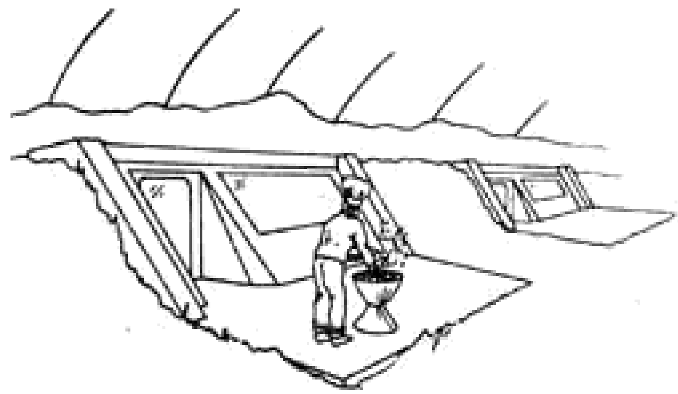
by David E. Cremer and Peter Kokh

The Prinzton design study aimed at outlining the general features of as comprehensive and full-featured a facility as a community of 3,000 plus souls could expect by mid-21st Century. But we also sketched some variations of rille-site structures.

NATURE PRESERVES: One of these was a hundred-miles-long *Nature Preserve* in a sinuous rille, complete with a recycling river, ponds and waterfalls, pockets of forest, meadowland, and marsh, herds of deer and other wild life, and a sightseer monorail for minimized interference and impact. This would be an inviting, soul-restoring extravagance further in the future, a dream to work towards.

RESORT COMPLEXES: More easily realized and sooner needed would be a *Resort Complex* offering safety-valve and escape features to make life on the Moon a little less harsh. Starting with the assumption that as individuals will spend only small fractions of their lifetimes in such a facility, we suggest that much less shielding mass be used. A much stronger single vault to hold the atmosphere with greatly reduced compensating overburden weight would be an attractive possibility *if* that overlayer were in translucent form. "Cracked" color-free or bluish glass above an air-tight sky-pane:? Layered thick panels of glass with zero coefficient or thermal expansion? Decisions for R&D.

Such a vault would offer a blue day-span sky without heliostats. If combined with cottages set into the rille slopes and having added shielding on their individual roofs, the shield mass above the vault could be kept to the minimum necessary to allow the desired degree of translucency. For not only would vacationers spend only a week or two a year in such a spot, call it "Lost Valley." they would spend perhaps a third or more of that time within the further-shielded cottages.



Vacationer barbecuing on cottage patio
Illustration by David E. Cremer

Plus, scattered hardened shelters could be provided for refuge in case the thinner vault was penetrated by a meteor-oid, a rather remote possibility, but still one much more likely than in Prinzton. The sky-pane could be electrically heated to 33 F during the nightspan and with natural drip-point texturing to allow the dayspan buildup of atmospheric water vapor to con-dense and fall as a gentle rain, spreading westward after the sunset. Earth's many "rain songs" would become popular.

Facilities for Staff

All staff housing, grocery stores, other shops, restaurants and nightclubs, maintenance facilities, etc., would be placed on the rille-shoulder *so that* within "Lost Valley" itself, there would be only cottages, playing fields, greasy meadows, forest groves, floral gardens, lagoons and trout streams, and an extra complement of people-hardy wildlife, etc. Not the seaside, nor the mountains (holi-day beacons on Earth) but a pastoral set-ting reminiscent of the green hills of the forsaken home world.

Casinos and Bazaars

One optional lure that might have merit is a rille-top casino with and and all winnings in the form of vouchers cashable *only* at a *luxury import emporium.*

This mecca would provide an invaluable safety-valve for the lunar pioneers who otherwise freely but wistfully accept major sacrifice of luxury terrestrial consumer paradise goods.

Location could be everything

Such a resort complex might be situated in any convenient rille. But one possibility, heightening the psychological getaway effect and offering extra out-vac excursion activities would be a *just-beyond-the-limb* site. For lunar farside nights offer eye-filling, mindboggling Earthless skies, dominated by the Milky Way shining with a brilliance and wealth of star cloud detail such as we Earth-imprisoned souls can scarcely imagine.

To give an instance, there are some SW-NE running rilles in SW Mare Orientalis or Eastern Sea (the great "bullseye" impact basin near 95 °W and 20°S about 1400 space-crow miles from the Prinzton site, some 40% of the route traversing highland terrain. Being just over the limb (by 5°) such a "*Bullseye*" site would offer the added drama of the Earth climbing just over the horizon and then settling back below it. This would occur every 27.5 days the Moon wobbles or librates from side to side slightly in its Earth-locked orientation. As this period is somet two days shorter than the dayspan-nightspan cycle, the timing of such events will drift. The sunlight phase of "the peek-a-boo Earth" would also vary. Quite possibly honeymoon-caliber stuff for future lunar pioneers.

It will take a thriving Lunar frontier economy to support such a resort. As the space-faring economy builds up, such a day *will* come.

C. QUESTIONS FROM THE READRS

Replies by Peter Kokh

Ed Marwick, Chicago Space Frontier:

I have doubts about fusing the lunar rille slopes and bottoms to form an adequate pressure/moisture membrane. This would produce a vitreous (glassy) surface that is susceptible to attack by water vapor in the air within the habitat.

REPLY: This may be so. But if some other, presumably organic membrane such as an epoxy sealant were to be used, it would still work much better over a solidified substrate. The point you bring up is one of the areas in most dire need of research and is pointed out in our article, "Lunar Architecture." in MMM #5, May '87 [article included in MMM Classics Vol. #1.]

The price of lunar settlement will remain stubbornly high if we have to use liberal quantities of Earth-sourced organic sealants.Anything we can do to substantially reduce this need will help. Fusing and glazing are certainly a first step because they reduce the general porosity at least to mere hairline cracks. Then, instead of an overall painted or sprayed coating, we can hot-pressurize the habitats with a sodium salt that will vaporize and seek out all the cracks, sealing them. Sodium will eventually be extractable from the regolith KREEP fraction. How we might keep such a membrane in good repair is another question, one which to date has received little attention by those better equipped to find an answer. Without an answer, *no* type of architecture based on lunar materials will give us the economic break-through we need to go beyond token outposts. It isn't only Prinzton that hangs in the balance.

Bill Bogen, Ann Arbor (MI) Space Society: I don't believe that using lunar regolith as a heat-sink would work very well. If the temperature is constant a few meters below the surface, it is because the regolith or rock is a good insulator, and as such, will not carry away excess heat from the settlement.

REPLY: Our point on the temperature of the soil is that it is significantly lower than the temperature comfort range a base will wish to maintain. So it is in that sense a heat sink, even if an inefficient one. We also carefully segregated from the main village habitat structures all those industries that would produce a lot of heat. These industries would be placed on the rille-top and would have to have their own heat-rejection systems. While we did not do heat flow studies for the village habitats, we thought that the combination of the cold soil and choice of low-thermal output activities would put us in the ball-park towards overall thermal equilibrium.

Bill Bogen: I presume that each of the three villages will have safety features in case an adjacent village is ruptured and loses pressure. I also presume that the walls/ceiling of each village will have a generous safety margin and could tolerate higher than average pressure. On that basis, have you considered using differential air pressure between the villages to store energy during the 14 day lunar nightspan? One advantage of this system is that little extra mass would have to be importe for energy storage. A *very rough calculation* seems to indicate that one village using a 10% pressure change could store about 7200 kilowatt hours, an amount my household uses in about 20 months. If this is so, it would not be near enough to be the prime energy storage means, but could act as a supplement.

REPLY: Safety in case of rupture was one of the reasons for choosing a segmented multi-village plan. (Other reasons include the ideal opportunity to stagger the work-time clocks of the three villages, so that everyone gets to work *their* day shift while the settlement's industries and services function on a 24 hour basis; and the opportunity to encourage different architectural styles, village plans, even flora and fauna.) We'd expect air pressure to fluctuate somewhat both with temperature and with the not-quite matched cycles of carbon-dioxide and oxygen production. But we'd hate to deliberately stress the system further than that.

However, as passive thermal and power systems are the ideal place to start, we'd be happy to have someone figure out if the natural pressure cycle just outlined has power storage, and release, potential. We never thought of pressure fluctuation as a an energy storage "flywheel." Rather, we looked on the water reserves both as means of thermal equilibrium (active, by the use of heat pumps, if need be) and energy storage (electrolysis-fuel cell cycle; hydro-electric cycle.)

Bill Bogen: What about a polar site for a rille-type settlement?

REPLY: There are no maria "seas" within 600-some miles of either pole, and rilles (as opposed to fault grabens) are exclusively a feature of the lava-flooded maria aareas. But the general concept of a two-tier, differential pressure, habitat structure should be adaptable to appropriately sized craters. If you could find three such in the same vicinity, you would be in business. Getting sunlight into such polar craters will be a *"tall'* order, but not impossible. Tower-mounted heliostats a minimum of 2,000 ft. above the crater rims (*at* the pole, other-wise higher since the poles are inclined by 1.5°) with fiber optic leads would be necessary, or else reflection off some high-hovering soletta, such as the Dr. Forward idea you mention.

More importantly, a polar settlement, while it may be needed to 'mine" water-ice, will be poorly located for lunar processing and manufacturing, simply because both poles are in highland areas, far from basaltic maria. Any settlement not *on or near* a highland/mare *coast"* will be at a disadvantage for resource utilization. The highlands are rich in aluminum and calcium, the maria in iron and titanium. Even if water ice is found, the poles will probably play a "*supporting role only.*" Any lunar development limited to polar areas will be limited indeed. The polar gambit is a "hare strategy." We prefer the "tortoise strategy."

Charlie Moore: How will suddenly appearing plant diseases be kept from wiping out all the crops? Will farming be hydroponic and sterile?

REPLY: This is a problem with which any settlement design must cope, not just Prinzton. Admittedly, Prinzton's use of megastructures enclosing large areas, as opposed to linked but separable modular pressurized units, makes one of the remedies available to a modular settlement unapplicable: *open the infected area to vacuum.* If the upper farmfield area was emptied of air, the upper vault would be in danger of collapse from its own now-unsupported weight. However, Prinzton's use of a two-tier structure might allow the farmfield to be sterilized by baking. Some way of relieving excess air pressure from the heating would be needed. It may be possible to maintain high biological isolation between the farmfields of the three villages until the infected one was brought under control.

We specified "raised bed" farming over hydroponics as the latter has many stubborn problems. There was no discussion of keeping a sterile environment. A ballanced microbial ecosystem that keeps individual mircobes in check, would be preferable if we have learned by then how to set one up and maintain it. Nonetheless microbes will be the real danger. Larger insect and rodent pests should not be a problem as careful measures (packing seed in heated nitrogen) should prevent their importation from Earth in the first place.

Charlie Moore: How will you handle population growth beyond design limits?

REPLY: Many foresee only a restricted future for lunar sur-face operations, one consisting or robotic and teleoperated mining operations coupled with a mass driver. We see a significant role for lunar surface manufacturing to support growing space markets. In time this indus-trial base should diversify to employ a *much larger* population. Neighboring village habitats can' be built in this or other nearby rilles or in rilles in other areas of the Moon. As to birth control, we might expect fami-lies to size themselves according to long-range prospects for continued economic growth. **< MMM >**

Glass/Glass Composites

Ongoing SSI-Supported Research

Brandt Goldsworthy, the President of Alcoa Goldsworthy, reports that testing of the feasibility of producing glass compo-sites from loose lunar regolith soils by solar heating will begin sometime this year (1990). McDonnell Douglas has a spare parabolic solar concentrator able to pro-duce temperatures above 3000 ℉ (1650 ℃) needed to melt the raw material, and has agreed to lend the unit to Goldsworthy.

Crude glass-glass composites on the analogy of fiberglass reinforced plastics (RFP) would be the easiest way to build structures needed for a lunar settlement using on site materials. Some further refinements could provide export-quality building materials for income-yielding export to space construction sites.

Shown below is an illustration of what such a highly automated early lunar industrial installation might look like - from Popular Mechanics.

MMM #34 - April 1990
CELEBRATING EARTH DAY #20

The Many Space Benefits for Mother Earth

Essay by Peter Kokh

The sense of Earth as a fragile Oasis in Space has been greatly enforced by the view from space. The snapshot of the "Full Earth" taken by the Apollo 17 crew during their return from the Moon is quickly becoming the most popular photo of all time. Earth-love is in. *Oasis-smarts are in.*

The contributions of Space Technology to the cause of preserving what we can of the biological and environmental heritage of the Living Earth as we inherited it from previous generations of stewards, are already considerable - even fundamental to our present attentiveness. Meteorology and communications satellites have played supporting roles to the various national Landsats. In their starring roles, these latter multi-spectral thematic mappers have not only afforded us an ever-updated real-time census of Earth's forests, agri-cultural lands, deserts, and the snow cover. They have also revealed land use patterns, and sown blight, drought, silt-content of waterways, red tides, and many other aspects relevant to understanding and realizing the true state of the envi-ronment and the rate at which it is changing, usually for the worse. To act appropriately, we need knowledge, and *Earth-monitoring satellites have provided us an "authority to consult.*

"You ain't seen nothin' yet!" goes the saying. The nine giant Earth Observa-tion Satellites (EOS) that will form the keystone of NASA's "Mission to Planet Earth" in the coming decade, are necessary both to give us accurate knowledge of all the key environmental "hot spots" and *the means of timely assessment of the effec-tiveness of whatever well-intentioned reme-dial measures we have taken.*

But the future role of Space Techno-logy in the battle to preserve - and then restore - the Earth goes will beyond its distinguished service as a vantage point from which to detect, observe, and monitor. In a somewhat belated, but extremely welcome admission, NASA, in its report to the President on Moon-Mars options, notes that by one or more of three options, *"the Moon has a role to play in the long-term supply of clean electricity o fill Earth's needs."* Those three options are:

- Solar Power Satellites
- Fusion power plants fueled by Lunar Helium-3, and
- Relay transmission of power form a ring of solar arrays on the Moon itself.

Clean electric power generation will not solve all of our planet's environmental problems. As we learn how to design the valuable mini-biospheres needed to re-encradle our settlements of unearthly horizons, we will learn lessons invaluable to our efforts to preserve and restore balances within Earth's surviving fragmented ecosystems. And as we learn to operate uttra-efficient and through recycling systems in these frontier communities, some of that technology will apply to situations below. This "Biosphere Benefit" will be major.

A "Healthy Earth" must also include a Healthy Cultural Environment with real opportunities to burst out of dream-squelching spiritual limits and horizons. It must express itself in a reinvigoration of education and of youthful dreams and opportunities. It can do this only through continuing interaction with and endless frontier. The renaissance of arts and crafts stimulated by frontier forms will be a part of this phenomenon.

Earth and the human soul will share a common fate. If , in misplaced concern, we act contraceptively to "keep Earth-life on Earth" in search of some lost pastoral Eden, we will have plunged ourselves into a Hell of o escape instead.

Earth Day 2070, the 100th Anniversary

What environmental achievements might we have realized Earthside eighty years from today as a benefit of space technology? Exploiting one or a combination of the three Space-Resource-Based options for eco-safe electrical power generation listed above, we could expect:

- a stabilization of the trend to global warming
- an end to acid rain
- some relief on the pressure to cut forest growth for fuel and for farmlands
- a spread of intensive greenhouse vegetable gardening
- a slowing of the pace in plant/animal extinctions
- a greatly reduced disparity in the general living standards between the developed and underdeveloped worlds.

No-holds-barred economics might give way to an alternate game based on Eco-custodial Economics. While nations may yet cling to their illusions of "sovereignty", various international institutions will channel a significant portion of their real inter-dependency. Modeling its acronym after an ancient Roman goddess of the Earth, **T.E.L.L.U.S.** or **T**errestrial **E**co-custodial **L**iaison and **L**ogistics **U**tilization **S**ervice, or something of the sort, may work to guarantee that previously slippery multi-national conglomerates operate responsibly.

U.N.E.S.C.O.rather than the old U.N. General Assembly may be the one body with representation from all Earth and off-planet nations alike. For while much of the U.N. agenda would be irrelevant and inapplicable off-planet, shared educational, social, and cultural concerns will always bind mankind's far-flung communities.

A.I.D.S. may no longer refer to the once dread and now long forgotten fatal STD, but rather to the **A**steroid **I**mpact **D**eflection **S**ervice, the current analog of military preparedness, only now aimed at inanimate objects capable of snuffing out life on Earth, rather than against fellow humans. And, whether we will have listened to "intelligent" radio signals from other star systems or not,

we will have detected
the oxygen-sweet "signatures"
of other "Earths"
around some nearby star-suns

"Earth Day" as celebrated beyond Mother Earth might naturally be transformed into a corresponding "**Children of Earth Day**" festival held throughout off-planet civilization. The matriotric toast - "To Gaia and the Gaiacules" - sums up the spirit of celebration of our Human-Gaian origins. Observed on a rhythm set by the adopted calendar-variant in use in each case, this holiday will become the occasion for rededication to the continued eco-custodialism and further bio-enrichment of all the offspring Oases of Earth-life that we have established throughout the Inner Solar System. - **PK**

RECYCLING

RECYCLING by Peter Kokh

[This outline of materials-management systems appropriate for Space Frontier settlements ALSO addresses some persistent Earth-side problems.]

Recycling is an integral and essen-tial aspect of our "tenancy" of whatever corner of the universe we occupy. It is *custodial common sense.* And if it is becoming sound economics here on Earth, it will be an absolutely vital cornerstone of economics on the Space Frontier.

ORGANIC & SYNTHETIC MATERIALS

First we'll need to recycle organic and synthetic materials derived from such volatile elements as hydrogen, nitrogen, and carbon which will not exist in the all-surrounding abundance we are accustomed to on Earth, even after we are able to supplement the vanishingly meager lunar sources with supplies from volatile-rich asteroids and comets. This self-discipline will be indispensable for Lunar Settlement, and highly advised for Space Colonies in near-Earth space.

Keeping the ratio of native lunar vs. exotic imported content as low as possible will alone allow any chance for a favorable trade balance and economic self-reliance. Thus priority must be given to our food and clothing needs in using these precious elements. The purpose of such an effort is to provide *the lowest* Cost *of living, by stretching the service life of any volatiles imported at great expense and by reserving them for uses for which there are no substitutes.*

INORGANIC MATERIALS

Contrary to intuitive expectations, it will also be salutary to recycle processed inorganic materials since they embody considerable energy expense already invested in extracting and processing them from raw regolith soils. The more energy-intensive a refined material is, the more to be gained from recycling it. Proper pricing of virgin materials will guarantee this outcome.

Tailings also embody the energy investment of their by-production, and using them to make secondary building products would capitalize on this investment. [See "TAILINGS" MMM # 25 p. 5. May '89 - republished in MMM Classics #3] Even glass cullet and ceramic shards can be used e.g. embedded in glass matrix decorative panels covers, fronts, handles and knobs. In the case of inorganic materials the purpose of all this effort will first be *to reduce total energy-generation requirements*, a strongly *economic* motive. Secondly, it will help settlers *to* minimize *the* Acreage *of surrounding moonscape that will need to be disturbed to maintain there a population of a given size,* an *aesthetic* goal. This "discipline" will allow us to tread softly and caringly on the magnificent desolation of an adopted virgin world.

Our strategy for realizing this authentic way of life will have many sub-targets. Appropriate product design, easy sortability, convenience, collection nodes, routing and route servicing, division of responsibility, supply versus demand volume-matching, entrepreneurial opportunities, youth and school involvement, contests, public discipline, tax incentives, and backup systems must all be given special attention.

RECYCLING - FOUR BASIC PATHWAYS.

(1) REUSING of all refillable bottles and containers is the most obvious *and* most economic.

(2) RECASTING by crushing, shredding, melting, and then recasting fresh items is another. We do this with paper, aluminum, and plastics for example. This method is greatly hampered by unnecessary cross-contamination with durably-bonded unlike materials. As for markets for recycled temporary-use items, building products/ furnishings best match supply.

(3) RETASKING or use-reassignment is a greatly underutilized third avenue. Timid examples are jelly jars designed for long reuse as drinking glasses and butter dishes designed to be reused as refrigerator ware. There have been at least three abortive efforts to design what has been termed a "world bottle", a glass beverage bottle ingeniously shaped to serve anew as a brick or building block. That is one task worth taking up afresh! Designing smaller high-fashion glass bottles for infrequently sold items, such as medicines, fragrances spices, etc., with a female-threaded punt on the bottom to match the male-threaded neck would allow combining these into stylish decorator spindles for any number of imaginative uses. Formulating packaging and packing materials to serve as craftstuffs for artists or even as fertilizer for gardeners is a promising possibility. In any such dual purpose design effort, it will be *critically important to find reassignment uses with adequate demand-potential to match, and use up, the full volume of supply.* Otherwise any such efforts will be but futile and distracting gestures.

(4) REPAIRING is one avenue increasingly being abandoned because of high labor costs.

Repair costs, however, could be greatly reduced by more careful *product design with greatly increased attention to assembly sequences and methods that are take-apart-friendly.*

The present quest for *seamless sophistication in appearance* is one of several sirens luring manufactures in just opposite direction.

To repairing, we might add **refinishing and totally fresh makeover**. Even where repair or refurbishing is impractical, if the item in question cannot be economically disassembled, then the sundry parts that would need separately recycling will end up being irretrievably trashed.

Only the adoption of design and manufacturing methods not now in favor will make all this viable. Lunar manufacturers will need to sing this new tune. *And*

frontier settlements cannot in the long run afford to import Earth-made items *not knock-down friendly*.

The extra cost of meeting these new requirements will be minor in comparison with Earth to Moon up-the-deep-gravity-well freight charges.

INSTITUTE FOR MOON-APPROPRIATE INDUSTRIAL DESIGN

No amount of recycling discipline on the part of our hardy pioneers will work without such a wholesale redesign of consumer goods. For this reason, we really do need to start *now* by establishing an Institute for Moon-appropirate Industrial Design.. While aimed at meeting demanding frontier requirements, the very constrictiveness of this challenge should make such an Institute the prestige *Alma Mater* of choice for industrial design students the world over, regardless of whether they had any intentions of ever leaving their comparatively soft Earth lives behind.

INDUSTRIAL ENTERPRISES

The significant *up-front* role of industrial enterprises in creating a material culture in which much more extensive and thorough recycling is possible than in our current American experience, is not limited to proper product design. It should be the highest priority of Frontier Governments, to provide encouragement and incentives *sufficient* to ensure that the principal avenue of industrial diversification involve new enterprises wins the by-product materials of those already in place. Again, *this compounds the productivity of energy already spent.*

Properly integrated industrial parks will involve *suites of industries in an ecosystem of traded by-products.* In one highly successful entrepreneurial effort in Texas a few years ago, an enterprising computer buff went from plant to plant, asking for data an any unwanted supplies, scrap, and by-products to put in his data bank. Within the first year, he was able to generate enough networking between sources of previously unadvertised supply and potential customers to take in a cool $5 million for himself.

"With *a good system,* even those who do not care, *will* do the right thing. Without a good system, even those who *do care, can't* do the right thing."

Given goods that are separable, sortable, and economically recyclable, the consuming citizen will at last have an honest chance to do his/her part. But it is not enough to know what should be done. Both citizens and government must also realize that without proper organization, on several levels, it won't happen.

SORTING

"A place for everything and everything in its place" is not only an unbeatable philosophy for managing one's basement, attic, and closets. It also applies to the home and business recycling corners. Instantly identifiable bins or baskets must be conveniently arranged for every category to be sorted separately. There is no reason that home recycling centers have to look untidy, a hodgepodge of Rubber Maid baskets and paper bags. A top priority household product should be some sort of bin-susan or bin-rack setup. Why entrepreneurs aren't turning such things out here and now is beyond my comprehension.

On the Space Frontier we'll need a greater number of different bins than we do here, where the economy is only organized to take in paper, glass, aluminum and some plastics. [Milwaukee's *Pollyanna Plastics* is now negotiating with area recyclers to take all the vinyl bottles and (!) polystyrene foam packaging they can buy back from the public, in addition to PET and HDPE plastics.] Glass and glax*, ceramic shards, and the various metals; refillables and tradables, used cotton cloth, fiberglass fabrics, thermoplastics, paper stuffs, dye stuffs, plus various compost categories all need separate bins.

A collection system with convenient nodes to see that all these items find their way back to the industries that can use them, is the next equally critical and indispensable element in the recycling triangle. Perhaps the electric delivery vans of the settlement could belong not to individual merchants but to materials circulation enterprises. They would pick up appropriate categories of disowned goods even *as* they deliver, a prerequisite for a license.

ALTERNATIVES AND OPTIONS

But there must be many *alter-native* routings to make a system work. If containers and packages in which shoppers bring things home are designed to collapse or nest compactly, they could be reused conveniently. It might even be bad taste to leave home empty handed! Drop-off Centers could be conveniently central to each shopping area. Properly arranged and managed (a place for every-thing, remember?) they needn't be unsightly. Featuring lockers, public toilets, cafes, they could include floral gardens, stalls for artists and craftsmen, repair and make-over shops etc. And why not arts & crafts classes, street music, dress-up fashion and bauble shows, and even a "soap box" for those eager to share their concerns?

COTTAGE INDUSTRIES

"Scavenge and Trade" licenses could be given preferentially to those with cottage industries based an giving new life to cast-off materials and items. Art du Jour, serendipitous temporary sculptures made from collected items, could be a major draw. Such creations might feature those items and sort categories for which the supply exceeds demand in the hope of stimulating would-be entrepreneurs and artisans to discover fresh unsuspected possibilities in such over-available stuffs. Demonstration classes in artcrafts using recycled and discarded items would be in order.

In Space Frontier pioneer towns, "recycling" may finally 'come out of the Alley"

Farm-Mart Centers, wherever grocery shopping is done, should not only take in the appropriate refillable containers but also buy/sell sundry categories of *compost* and composting accessories such as paper stuffs (e.g. corn husks) and garden and kitchen scrap dye stuffs, bone, and fat could be handled separately from any compost that exceeds home garden needs.

Jailed inmates could do the heavy duty labor intensive disassembly work; pardons might be in order for those demonstrating their capacity to function as useful citizens by entrepreneurial development of markets for orphaned and high surplus sort categories clogging the network.

Primary and Secondary School involvement will be crucial in making the system work. This is the subject of the next article. [see "The 4th R" just below]

ROLE OF THE UNIVERSITY

Finally, the frontier University has a role to play as orchestra leader.

The University, not government bureaucracy, must assess how well the system is working, and develop needed improvements.

A University office would maintain the computerized current inventory of various depositories with a disciplined materials accounting system monitoring supply/demand imbalances, and circulation efficiency, assign identifying sortation logos and routings for new classes, and maintain updated guidelines on a utility cable channel (or website).

The University should supervise and assist entrepreneurial experimentation in its labs and shops to develop new materials and products that will take advantage of various kinds of discard stuffs that are in excess supply. As such it will be *a principal incubator of new businesses and economic diversification.*

The University's Institute of Industrial Design would work to find new ways to implement such philosophies as "whole sheet" scrapless design of product/accessory combos, "kosher" assembly of unlike materials for later ease of separate recycling, "honest surfacing" that utilizes the design advantage and character of materials undisguised by surface treatments that make proper sorting identification anything but easy.

VOLUME REDUCTION STRATEGIES

Not only must we provide for proper sorting and routing of items to be recycled, we must take care that the system is not overwhelmed. Volume reduction strategies are in order.

In the USA, 40% of trash is packaging materials.

In MMM # 4 April '87 "PAPER CHASE" [republished in MMM Classics #1] we pointed out that wood, paper, and plastics will be prohibitively expensive. This whole fascinating topic of how to service the diverse packaging, labeling, and even the advertising needs of the settlement with minimum reliance on precious volatile-rich materials, that should be reserved to increase the mass of the biosphere "flywheel", will be the subject of a separate article in a later issue of MMM.

SUMMING UP:

We must not allow either Lunar or Space Settlements to be "born addicted" to a technology and culture of abundance and waste. All those elements needed to make this ambitious program work must be developed beforehand, pretested and predebugged before lunar settlement begins.

It would be best if as much of this as is appropriate could even be ready to go for the first NASA/International Moon Base. Those of us interested in off-planet settlement must begin the cooperative addiction-treatment program that will enable such a propitious fresh start, as well as create spinoffs that will aid in Earth's own environmental struggles.

Beating this addiction, from which we all suffer, will require a "wartime" dedication and inventiveness. Only to the degree we succeed will we prove ourselves worthy citizens of Earth's con-solar hinterland. **< MMM >**

"The Environment" -
whether on Earth or on the Moon it's a question of pay now, or pay much more later.

THE FOURTH 'R'

THE FOURTH 'R' by Peter Kokh

Here on Earth, we imagine we can afford the luxury of continued general ignorance of the way our Biosphere works and what may be necessary to maintain its health. We allow our young people to drop out of school, and allow those who do complete their courses to graduate with empty heads. We assume Mother Earth will go on taking care of itself as it has from time immemorial. Those that want to worry - that's fine, let them do their thing. The rest of us - let's party!

In the miniature oases of life that *Ecotects* design, build, and seed with life on the Space Frontier, we will have no such luxury of aloofness or ignorance. Whether we prefer to live in space colonies, in lunar settlements, in pioneer Martian towns or elsewhere, the carefully set-up envelopes of Earth-life, water, and atmosphere we'll need to coddle our existence beyond our native womb-world, will have minimum tolerances for healthy functioning. The ecological facts of-life in the *fragile exclaves of Gaia-Humanity* will be immediate in their critical importance.

A Space Frontier *Biosphere* or *Oasis* might be described as a closed mini-world where everyone "*lives downwind and downstream from themselves*".

This means relentless vigilance in keeping the water and air clean beyond any standards set on Earth. Food chains will be short or telescoped. And waste biomass and organic materials must be efficiently and quickly recycled.

To keep low both energy consumption and the need to radiate excess heat, we'll need to get the most product per energy-input/heat-output as possible. Recycling, which recycles the *energy* of original processing as well as goods themselves, will be essential for all classes of materials.

Back on Earth, environmental consciousness is rising and is now the highest we've ever known. Yet, polls show people only care enough to want "someone else" to take care of the problem, and to do so without causing any personal inconvenience or forcing unwelcome changes in lifestyle.

It should be clear that if any such attitudes were common within a Space Frontier Biosphere, an environmental catastrophe most likely without hope of recovery, would follow all too swiftly. Nor will it be enough to have "a high level" of individual responsibility. *Everyone* within such frontier communities has to be *"oasis-wise".* It must be *Second Nature* to the Pioneers to *live as if the dawn of the next day depended upon* their rigorous respect for the Biosphere-Facts-Of-Life. For indeed, we'll survive one day at a time.

The only way to guarantee an oasis-wise citizenry, is to teach "Eco-Sense" to the children, not as an elective, nor as a mere requisite for graduation that can be put off to the last minute, but as one *backbone* of their education. Recycling - of the air, water, and biomass; of organic, synthetic, and inorganic materials - must be as important as Reading, (w)Riting, and (a)Rithmatic. *Children* must be taught *Recycling as the Fourth "R"!* Eco-responsibility has to become second nature. For if it is something we have to "remember" to do, we'll only do it when it's convenient or when someone else is looking.

Space Frontier Schools will have then a major role to play in guaranteeing the survival of the settlements they serve. The pioneer youth must learn not merely how to sort discarded items properly, but have a good understanding of how used air, water, biomass, and the various sorts of consumer materials are each routed back into the system upon which their shared lives depend. They should understand the raw materials and by-products interdependence of industries and the interrelatedness of all those kinds of life that make up their mini ecosystem.

Students could be assigned recycling *chores appropriate to their grade level* to give then hands-on appreciation of how things work. The goal is not merely to produce good consumers and insure oasis-wise home-economics, nor merely to produce good entrepreneurs, industrial managers and workers, but to ensure that each citizen has sufficient appreciation of the Biosphere-Facts-Of-Life on which community survival depends, to vote intelligently and support only responsible political efforts. For while "lunacy" can be tolerated on Earth, there's no place for it on the Moon itself, or elsewhere in space.

PRIMARY SCHOOL

In Primary School, rote learning of the types of things to be sorted and recycled separately, of their names, identifying clues, and routes by which they are cycled back into the system, and of the current market uses of recycled items can all be gradually introduced. In art classes the students would use only oasis-wise media and craftstuffs, coloring agents, and finishes.

In frontier homes children could gradually be entrusted with the responsibility to monitor and manage the recycling chores within their households. They should be introduced to kitchen and garden composting, learning which food or garden scraps need to be treated separately. They can be encouraged to make things of pride from materials and discarded items.

No small part of early education would be to equip youthful vocabulary with sets of keywords and phrases having strong positive connotations. "Trash" and "Wastes", words of ill-repute, could be replaced with "Freed" used as a noun i.e. stuff relieved of previous service and ready for reassignment. ("Tommy, please drop off the freed on your way to school.") The rehabilitation of "alley economics" must start with the young.

HIGH SCHOOL

At the High School level *the entire curriculum should reflect Biosphere-Facts-Of-Life.* In the teaching of Biology, attention should be given to natural air and water cycles and the steps at which these processes may need assistance within the mini-biosphere. The time it takes to biodegrade biomass waste and various types of organic materials should be covered. Not only should the Chemistry of atmospheric gasses be taught but also the nature of toxins, how they are produced both-in nature ad industry, and they can be neutralized or prevented.

In teaching Import/Export Economics, the very critical role of recycling volatiles and already embodied energy must be stressed. An honest "Materials Accounting System" ought to be taught with its corrective affect on Financial Depreciation and Expense Accounting. And as an ongoing class chore/project, the economics class could maintain a Computer Database on some subset of recyclables under supervision of the University.

In industrial arts the concept of Whole-Sheet Scrapless Design can-be-brought home with school contests ad competitions. Entrepreneurialism in the service of recycling can be encouraged by the J.C.s and in Junior Achievement projects, stressing the use of recyclables for which the market is slow. Industry could provide school art classes with access to slag type sources of "accidental art" to be mounted or set for sale.

A very useful Extracurricular Activity, with supervision, would be to take in worn, broken, parts-missing, and cast-off small durable items, especially including toys. These could then be repaired and rehabilitated. And where this is impractical, the items could be disassembled so all materials needing to be recycled separately, can be. Time can be allotted for "Serendipity" ephemeral sculptures from such parts.

UNIVERSAL CIVIC SERVICE

Nor should this "immersion" in the spirit and process of oasis-wise recycling stop with graduation from high school. In space frontier communities, where there will always be more to do than people to do-it, a Universal Civic Service after high school might not be a bad idea. Manning and maintenance of streetside recycling nodes, with care for their attractiveness and efficiency, operating other nodes in the recycling system, and other "schleping" chores such as accident cleanups and maintenance of Parks and alleys are one way a *"Citizen-Candidate"* might pay his/er *dues* to frontier society.

Biosphere Maintenance is another appropriate dues-paying activity: i.e. manning the water-treatment and air-freshening facilities, various yeoman farming duties such as sorting spoiled produce and other biomass "freed" into mushroom matrix, animal fodder, and general compost.

Apprenticeships in the trades using recycled materials might also be considered for citizen-candidates if there are not enough of the above-listed job slots available. Cleaning refillables and other labor-intensive duties in the various recycling chains may also be in order.

The grand result of this thorough three step education process (primary and secondary schools followed by a stint of universal civic service) would produce Space Frontier Citizens who fully appreciated the fragility of their particular oasis of life and who forever remained deeply predisposed to live and act in a oasis-wise manner. We might even put some of these education ideas to use right here on our home planet. **< MMM >**

MMM #35 - May 1990
Asteroid Theme Issue

PORTS OF PARDON

PORTS OF PARDON - by Peter Kokh

Bring up the idea of using convicts to open up the less attractive and more remote reaches of the space frontier, and you are likely to get immediate and mixed reactions. Some will shrink in horror at the "cruel and unusual punishment" seemingly implied. Others will be more open, invariably citing the origins of New South Wales in Australia, back in 1788.

In that instance, the *"Sirius"* was the flagship of a fleet that included an armed trader, three store-ships and six transports. Aboard were 202 marines of various ranks, five doctors and a few mechanics, 40 women, and 756 convicts. They landed at Botany Bay at first, then moved to Port Jackson, the heart of modern Sydney. Later other convict ships arrived. The first "free settlers" arrived five years later in 1793.

However, that is not exactly the sort of situation whose applicability to the space frontier we wish to examine. It would be prohibitively expensive to use space destinations of whatever kind as "prison sites" far Earth's unwanted criminals. The ultimate *Alcatraz* or *Devil's Island* is not our topic here.

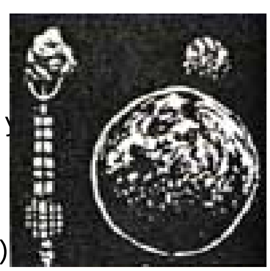
Quite the contrary! First, we propose to send there, not criminals from Earth, but those from Space and Lunar Settlements who prove to be resistant to reform. Second, we are looking at "Quarantine Sites" not prison sites. Unlike the situation at Botany Bay, these "convicts" would have neither wardens nor guards. Once on their way, unable to return or to change course, they would no longer be convicts, but freed men (and women in more nearly equal proportions - another difference from New South Wales) in collective charge of their own destinies. Those readers who have read the essay by Louise Rachel [in Moon Miners' REVIEW # 4, January 1989] entitled "Ruminations On The Uses of a Frontier" will recall one of her well-taken points that many persons who inevitably become misfits in a settled and highly structured society are able to function quite healthfully and productively in a wide open frontier.

A hypothetical Gallup Poll might show most people to be of the impression that "the guards" keep the order in any prison. But that is no more than a superficiality. From time immemorial, in prisons throughout the world, it is the prisoners themselves who both structure and maintain what-ever real semblance of order there is in such places. Like chickens or wolves, any group of felons will quickly find its own system or "pecking order". *No,*

no guards or wardens need stand by,
so long as escape is unlikely

For example - and for sake of argument - a one-way settlement expedition could proceed for Ceres or some other potential Regional Belt Center, wholly crewed by convicts "pardoned" for freely accepting the option. They would have on board all the equipment and the knowledge stores needed to set up a self-sufficient settlement that will not need resupply other than by drone freighters for the near term. When it comes to opening up boondock areas of the space frontier having all the popular appeal of some latter-day Siberia, such a scheme might not be an unacceptable way to get the job done.

In such a situation, not only would the "convicts" be legally pardoned, they would tend to cease acting "like criminals". Up against a hostile and barren environment, their survival would depend on mutual cooperation, a lesson that would sink in at the earliest inevitable opportunity. Nor need they be pre-trained for the mix of jobs and tasks needed to guarantee the settlement's survival. So long as the necessary knowledge was stored in libraries on board, individuals would quickly self-select their niches in the do-or-die community-to-be, highly motivated to learn all they could to make themselves valuable if not indispensable (the one sure means of individual self-protection) during the long months of the outbound passage.



Never again, would they have a like opportunity to enter a society on an equal footing with everyone else. For this settlement would be started from scratch socially as well as physically. The stubborn would quickly find themselves examples of harsh frontier justice.

Yes, the society that would emerge would be rough and crude at first. What may pass for justice might seem a parody of what we hold dear. But that would all change. Contrary to the doctrines of some, criminal behavior is not "in the genes" at least not in a sense that such behavior is necessarily inherited.

Revisit such a "Port of Pardon"
a generation or two later, and
you will find a society with
increasingly genuine legitimacy,
with deserved civic pride,
and real achievements,
both industrial and cultural,
worth boasting about.

Convict settlement opportunities need not be restricted to those already in serious repeated trouble with the law in lunar or space colonies. Those still operating within the law - just, and chaffing at the bit, could apply to join such endeavors. They'd need to sign releases holding harmless established authorities for untoward personal consequences of joining such groups.

Such a proposal achieves these three goals in the most economical fashion:

1. Establishment of badly needed settlements in unattractive locales without the lure of very expensive inducements.
2. An alternative to building and maintaining expensive traditional prisons in space or on the Moon.
3. A sure-fire way of rehabilitating those who just don't fit in, while protecting mainstream society in the process.

The alternatives of traditional imprisonment are not only considerably more expensive but also rather unproductive in comparison. Nor are customary ooptions more just by any standards that will bear scrutiny. It’d be a costly mistake for all concerned to dismiss such kill-three-birds-with-one-stone options without an honest trial.

The bottom line is that there may be no way to attract volunteers to the solar boondocks in numbers enough. **< MMM >**

WILDCATTING COMET CRUDE

SEARCHING FOR IMPOSTOR ASTEROIDS

by Peter Kokh

THE STAGE IS SET

The Moon, whaving been formed “hot” is relatively depleted in the volatiles necessary to support life: *hydrogen, carbon, and nitrogen.* We do not know yet whether the permanently shaded areas of the Lunar Poles harbor comet-derived ice, or whether, if so, how feasible it will be to tap. It could be that Lunar Settlements can make do. If not?

The Thirst For Volatiles, those elements in short supply on bodies like the Moon that may have formed "hot" and have been able to hold on only to those elements with high melting and boiling points, will be the organizing driver for opening and settling the space frontier. Included are water/ice (or at least the hydrogen needed to make water from scratch with abundant lunar oxygen), carbon, and nitrogen, and other elements needed in considerably less quantities.

Thanks to our harvest of the meteorites that have fallen to Earth (i.e. the ground), we have found that a considerable proportion of their parent source bodies contain economically recoverable amounts of such elements. Matching the laboratory spectra of these meteorites to those obtained at the end of a telescope trained on various asteroids, we are able to classify many of the latter, according to mineral content, with a fair degree of confidence.

Carbonaceous Chondrites offer us the prize we seek, a volatile content in the 20% range "soaked" in comparison to the Moon! Among the best known of such bodies are Ceres (far and away the largest asteroid), Pallas, and possibly the Martian moonlets: Phobos and Deimos.

Some of their volatile content may be in ice form, but some is also chemically loosely bound, molecule(s) to molecule as "water of hydration". Examples of hydrates (which feel dry, not wet despite their content) are gypsum, soapstone, concrete, and blue vitriol (copper sulfate).

One already popularized scheme for recovering such volatiles would begin with identifying mountain-sized carbonaceous chondrite astrobits. A mass driver would be attached, using the unwanted "dirt cheap" silicates for mass to be ejected at velocity. This means would kill two birds with one stone: bring the asteroid chunk into handier proximity to the Earth-Moon system; and begin the process of volatile extraction.

While many are excited about such prospects, we wonder if there are not much richer caches of ice in similarly near-Earth orbits, promising much more of a reward. The unexamined common viewpoint is that asteroids are asteroids and comets are comets, the latter being principally volatile in content so that if they approach the Sun much closer than Jupiter, they begin to outgass producing the familiar comae and tails. Harvesting active comets may seem a very tricky business; we'll leave that for a future article.

The one salient comet-fact almost universally overlooked is that as comets lose more and more of their mass with each orbital swing in towards the Sun, some of the less volatile, and possibly more viscous stuff, does not get carried away as gas and dust in the tail, but accumulates in an ever thicker blanket of "slag" on the surface.

The amazing photographs taken of Comet Halley - no thanks to Congress! - revolutionized our picture of what comets are like. Yes, we still see them as great dirty snowballs, but now we know that they accumulate slag crusts, and that all the great outrushing of vaporized materials comes not from the surface in general, but only from the few open pores that the slowly growing slag layer has not yet succeeded in plugging!

Prior to this discovery it was the common belief (and still is for those who have yet to make the paradigm switch these photos call for) that comets continue to outgas, getting ever smaller, until they just waste away, to nothing. That is probably not their common fate. Instead it now seems far likelier that comets eventually suffocate themselves, plug their flash-pores and "turn off", retiring into a cocoon of slag that they have gradually spun for themselves. They await a metamorphosis, a butterfly transformation into rich water reservoirs for thirsty "homo circum-solaris". For the vast bulk of the original endowment of dusty ice/snow remains "dormant" inside. Comets, in general then, do not die. They fall into a deep coma, awaiting some future "resurrection" and final justice.

The only article coming to our attention that hints at such a pregnant end to active comet life was written by Sheboygan (WI) NSS member Harald Schenk and appeared early last year in _Shores beyond_ the independent newsletter (now part of **MMM**) he edits for the Sheboygan Space Society. We reprinted the article in the August '89 **Moon Miners REVIEW**. In "Transition Comets', Schenk reviews work done by Brian Marsden and others which indicates that some bodies classified now as asteroids may be indeed "impostors", dormant comet hulks. The evidence that gets behind their *incognito* masks does not come from ground-truth penetrators, nor from tele-spectral studies, but from orbital analysis.

Most comets have characteristically wilder orbits than asteroids, not clustered within 10° to 30° of the common plane of the Solar System (the Earth-orbit-defined ecliptic continues to be the inappropriate standard in use), indeed as often as not orbiting in a direction opposite to the otherwise system-wide common one (anti-clockwise viewed from the north by arbitrary convention). Thus asteroids in highly inclined or retrograde orbits, and those in extremely eccentric orbits, should be under suspicion as pretenders.

The next step (with the highest priority and urgency!) will be to do thorough spectrographic, photometric, and radar studies of such non-conformist asteroids and see if they have a common tell-tale signature. We suspect this will be the case. Once so armed, we can then turn our attention back to the vast majority of asteroids with more commonplace orbits and examine them one by one for the same give-away quirks in the light they reflect towards us.

For luckily not all comets have orbits wildly askew from asteroidal norms. Comet orbits are statistically random, and a definite percentage of them will have the "delta-V reachable" orbits of Earth-approaching asteroids. And these too must eventually grow comatose. It will be this cluster of Sleeping Beauties that become targets for the adventurers wildcatting for comet crude. **< MMM >**

FEUDALISM IN THE ASTEROID BELT

By Peter Kokh.

A life prospecting and mining "off the beaten track" out in the Asteroid Belt is an appealing future for many. Out there in all that vast empty space, is escape from the sometimes suffocating and choking pressures of life in those highly structured and more densely populated regions of the familiar human range.

Such a romantic vision, as effective as it has been in inspiring the research necessary to make it possible, bears closer examination. Our purpose here, is not to rain on anyone's parade, but to make sure we take an umbrella along.

Yes, all that vast empty space! It's far far emptier than most of us would expect, given the Science-Fiction image of Asteroid Belt crossings as fraught with the peril of imminent collision with closely spaced astrochunks. So we continue to be amazed that none of the two Pioneer craft, or of the two Voyager probes even "noticed" that they were passing through this infamous zone.

Astronomers have identified, numbered, and calculated orbits for 3000-some asteroids, “minor planets”, as they are more accurately called. We have caught fleeting glimpses of another 2000 or so, and now suspect that there may be as many as 50,000 mountain-size or larger bodies orbiting the Sun between the orbits of Mars and Jupiter.

Seem like a lot? Let's roughly calculate typical random spacing in the belt between asteroid neighbors orbiting in formation or passing by in various criss-crossing orbits.

For sake of argument, lets stake out the region from 180 to 380 million miles out from the Sun and with a thickness above and below their mean orbital plane of a combined 100 million miles. That gives us about 3,500,000 million million million cubic miles or 700 million million million cubic miles for each. Take the cube root of that and you have an average close pass of 9 million miles. Limit the survey to larger asteroids, and their real mutual isolation becomes even more apparent.

Now remember that for the foreseeable future, the percentage of this "horde" that will bask in the new-found warmth of human attention will be rather small. Now IF the driving force of that activity is "Economic", there can be *no possible effective* source of law and order to police such a vast beat! Whether we are dealing with lone prospectors, homestaking families, large roving rival companies, or a scattered few settlements engaged in service, repairs, and supplies, this "legal" void will be inescapable. Even with a horrendously expensive thousand unit asteroidal police force, average response time to even the most dire emergencies would be hopelessly slow.

It would be naive to imagine that in such raw frontier conditions there would be no claim-jumping, no piracy, no extortion, or no rape and plunder. High reward has always been associated with high risk. Opportunities for hermit-like freedom to do one's own thing will come hand in hand with unimaginable material hardships (the nearest K-mart may be a year's journey away!)

Crimes of opportunity may well be a problem. But, even allowing for some magical angellification of the human species between now and then, other life and death emergencies are sure to arise - and dialing 9-1-1 won't help much.

"Belters" will need to face unflinchingly and without regret whatever unpredictable and not-personally intended dangers and disasters come with the territory of great opportunity. Those who can't do this cheerfully are best advised to "stay in Baltimore" - or wherever life is more genteel. "Belting" won't be for everyone!

What can happen? Medical emergencies, such as a disease or trauma that can't be handled locally; equipment breakdowns after one has used the last salvageable spare parts; a pressurization failure; an imminent failure of the life-support system; contamination of food supplies; a irreversible crop failure; not to mention mischievous interference from "visitors".

Most such crimes will have have to be borne without recourse to rescue or outside assistance even from the willing. There will be rare times, however, when aid is just barely possible from a "neighbor" or from a ship cruising within range. But more than likely, such aid will involve extreme inconvenience for the would-be rescuer: changing course and possible forced cancellation or permanent interruption of one's travel course or otherwise expending precious fuel reserves; dropping one's own important duties and projects for a lengthy rescue mission; etc.

In truth, Belters will prudently minimize the risks by choosing from suitable asteroids within tolerable range of full service centers (like Ceres, Vesta, etc.) or those within fair range at least temporarily. To do otherwise would be to tempt fate rashly.

HELP, AT A PRICE

Prudence will also give rise to cooperative mutual assistance pacts. These will have to spell out terms for compensation for economic consequences of going to another's rescue. Even such pacts cannot be expected to offer anything approaching full coverage of one's exposed butt.

Suppose some disastrous equipment failure in your mining camp threatens not only operations but the lives and safety of your employees and possibly the families they may have been allowed to bring along. There is no one within range or who can come to your rescue without accepting critical financial harm to himself. Mercy and compassion aside, what gain could possibly drive anyone to jeopardize his own probably precarious financial position by acting like a knight in shining armor? Suppose there is nothing that can be done to save your operation and habitats and that all you can hope for is a lifeline? It would seem that you are doomed unless you and your charges agree to work as indentured servants of your rescuers for a negotiable number of months or years. Some may choose to perish.

Certainly some sort of generally accepted code for crisis situations will need careful consideration. It will be advisable to have tentative protocols adopted BEFORE Belt development begins in earnest. These could be gradually adapted and supplemented as real-life experience warrants.

In the face of the possibility of real-life situations which, through some debt of rescue or by outright piracy, could result in the loss of freedom and influence over one's destiny, would-be belters will further lessen the contrary odds by carrying survival pods and lifeboats and by conducting periodic disaster drills. They might also carry with them courtesy drone rescue lift-rafts to toss one another. The likelihood of concluding a binding Mutual Aid pact with other parties may depend upon both being so equipped.

There should also be Special Courts in the full service center settlements to adjudicate any debts incurred in rescue efforts and to arbitrate the length of agreed upon indenture service. There would be courts in such centers anyway to take care of claim conflicts, payment disputes, and all other ordinary judicial fare.

To get a better grasp and appreciation of the challenging situations Belters could find themselves in and of the social consequences which would tend to follow, we would do well to study some of the loose parallels from other times in human history. Population sizes are likely to be individually very small: what aspects of Hunter-Gatherer life would translate to Belter experiences to come? A Belt-wide law enforcement fleet is quite impractical. A similar vacuum of authority existed throughout the Middle Ages: what aspects of medieval feudalism are we likely to find reappearing in the Belt?

It is not only law, order, and crises management that we need to get a handle on. The severely isolated situations in which Belter mining parties and small communities will find themselves has little real precedent in human history. Even the earliest Polynesians in their far-flung island chains were effectively much closer together, the incidence of their interactions being higher. What effect will such an extreme scattering have on cultural continuity and or educational opportunities?

Will inbreeding be the norm? Or will chance encounters be taken advantage of for hastily arranged marriages and liaisons with little time left for such relatively recent luxuries as 'first falling in love'?

In Australia, serving the scattered little railroad hamlets strung in a well-starched line across the Nullarbor (means "treeless") plain, there is a regular train affectionately called "**The Tea And Sugar**" which stops at each of these places. This train serves as the sole life-line for those living along this desolate route. One could imagine Belter operations preferentially so arranged that some sort of Catering Caravan or at least single Trader Ships could service them by some reasonable route. Working against this idea is the fact that the asteroids each have their own orbits, differing in period and thus in orbital speed. As a result, any route-logical array of mining operations and hamlets will will only be a fleeting one. The premium will be on suitable asteroids with an orbital period and velocity as close as possible to one of the various service centers so as to maintain formation with it over a period of some decades. [See MMM # 24 April '89, "CERES" - republished in MMM Classics #3].

Talk of wanting "to Pioneer the Asteroids" is perhaps somewhat dishonest in the light of these realities. Or it may be better to say that it betrays a dual ignorance, first of the bitter 'geographical' facts of life in the Asteroid Belt, second of the depth of one's own readiness to cope with the full intensity of the isolation that such a life may entail. A bitter fruit!

Saw will question this assessment, leaping forward to the prospects of great new propulsion systems that will offer "easy and swift" casual travel to shrink the great distances into irrelevancy. Or perhaps the reader will insist that the mineral wealth to be gained is so great that the expense of maintaining whatever police force may be necessary will seem minor. They may be right, and optimistic Science-Fiction scenarios may turn out to be accurate forecasts after all.

Perhaps the truth lies in between. The early decades for Asteroid Pioneers will be ones of harsh privation and sometimes tragic hardship. But in time, any tentative colonization of the Asteroids will whither and die out if the conditions and quality of life do not vastly improve.

If you still want to be on of the earliest trailblazers, all the same, you have my respect. "May the Force Be With You." You are going to need it! And WE WILL DO IT! **< MMM >**

TEA & SUGAR

TEA & SUGAR - by Peter Kokh

In the preceeding article, we made mention of the famous traveling "Grocery Store Train" that crosses the hundreds of barren miles through the states of South Australia and Western Australia. [An illustrated article on the "Tea and Sugar" is featured in NATIONAL GEOGRAPHIC, Vol. 169, NO. 6, June 1986, pp. 737-57]. Perhaps such ensembles will one day service the far flung outposts of humanity on these lesser worlds 'swarming' beyond the orbit of Mars.

Whether they will be mini-fleets, single larger ships, or perhaps variable “consists” more on the analogy of river barge trains, they would ply ever changing "routes of opportunity" between mining outposts as the host asteroids continually shift co-location patterns in their endless orbit-jockeying.

What facilities, tradesmen, and amenities could such ***Tea & Sugar***s offer to the isolated pockets of humanity they'd serve? Bear in mind that to some extent everyone in an outpost will need to be a jack of many trades. Yet in such small and isolated samplings of humanity, there cannot possibly be represented the full range of abilities, talents, trades, arts and professions needed to stave off an inevitable cultural and social decline through sheer malnourishment.

While each outpost will almost certainly have a general practice physician, the Tea & Sugar could have a clinic with a pediatrician, a geriatrician, a neurosurgeon, an orthodontist, and other specialists. A magistrate to take care of minor legal loose ends; troubleshooters in electronics and mechanics to handle stubborn problems; experts in agriculture, waste recycling, air and water quality, and general small biosphere maintenance; dietitians; a habitat architect - all of these would be welcome visitors at what is likely to be irregular long intervals.

This visiting caravan could include a stable of craftsman and artists who would make things during the long in-between journeys for sale at each stop. Or conversely, the T&S could take on arts and crafts on a consignment basis at each stop to trade at the stops to follow.

Young lads and lasses in such outposts might soon learn the little their elders could teach them, probably far less than their capacities and aptitudes would take them if they could have access to a larger population. So when the T&S calls, their parents might send them off on this traveling boarding school to learn from the tradesmen, artisans, and specialists aboard and to benefit socially from the companionship of youngsters from other outposts before the T&S brought them back home the next trip around.

Thus the T&S could sever well as a traveling school also, even offering certificates, validating diplomas, etc. For this purpose, several teachers and tutors might be aboard, perhaps having signed up for a tour of "public service" duty out of some home port population center on one of the major asteroids like Ceres or Vesta.

Such a chance to get away and see the worlds would provide an essential element of education that could not possibly be offered within a lone outpost, no matter how well-stocked its library and data banks. The young people would have a chance to visit other outposts at each port of call, to see and experience other ways of doing and living. A spirit of kinship would grow that would stay with them throughout their lives and generate a sense of Asteroid Co-nationality.

Friendships made on the T&S might well be the seeds of future marriages, partnerships, and joint ventures of various kinds. The Tea & Sugar type caravan plying these shifting Belt-lanes, would clearly be more than just a nice luxury making Belt life bearable. It would provide the glue holding all of Belt Civilization together. These caravans would swiftly become the "Mobile" Infrastructure without which any opening of the Asteroid Belt would not long succeed.

How would an outpost pay for T&S services? Surely not by public taxes! A Belt-wide government is just as much a wild-end impracticality as the police forces needed to maintain it.

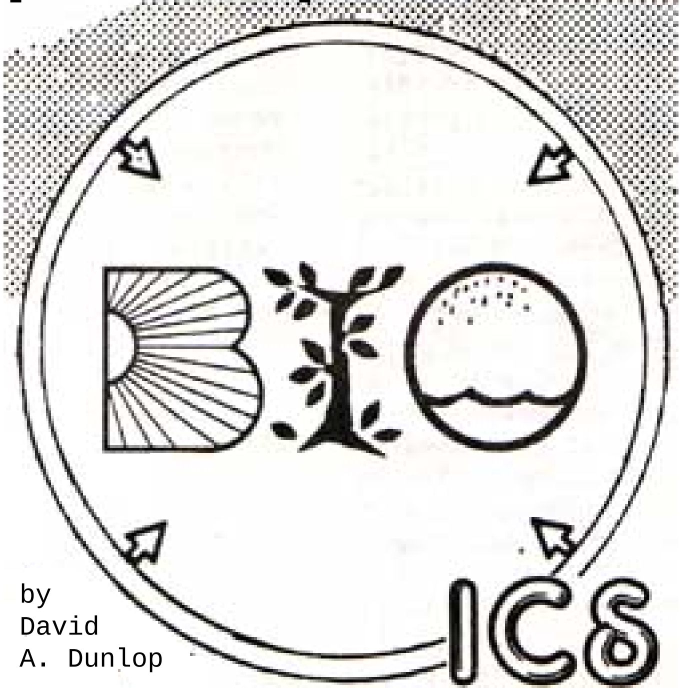
Outposts will of necessity produce their own fuel to run generators, machinery, and vehicles. They could refuel the T&S caravans for free, and perhaps replenish some pantry supplies. Further they could trade some of the mineral wealth they have mined. The problem does not seem to be that outposts cannot afford such a service.

Rather the problem is that outposts cannot survive without the T&S caravans whose operators will have the miners at their mercy, able to extort more in payment than is fair, reasonable profit included. Nor will competition keep the costs of outpost visits down. There may not be enough of a traffic pie to divvy up.

The pragmatic solution may lie in cooperative ownership of the T&S companies by the mining operators themselves. Time will tell. **< MMM >**

MMM #36 - June 1990

[BIOSPPHERICS]



by David A. Dunlop

DESIGN AND STRATEGY ISSUES FOR LARGE LUNAR BIOSPHERES

The development of a 3000 to 5000 person community will only be cost feasible within a 25 to 50 year time-frame, if it feeds itself and dependent Cislunar and Low Earth Orbit (LEO) populations. Doing this will leverage the economic advantage of abundant lunar oxygen which can provide half the mass of all plant and animal tissues and 8/9ths of the mass of the associated water. Foreseeable cost per pound, Earth surface to LEO and to cislunar and lunar surface locations, require such a "grow your own" strategy to save the unnecessary import cost of this oxygen content. Importing such high-oxygen content items as food and water to the Moon would be like bringing "Coals to Newcastle".

The substantial savings (circa 95%) in fuel costs of similar payloads launched from the Moon over those launched from the surface of the much more massive Earth, will give lunar-grown food, and water constituted with lunar oxygen, a 48% and 73% price advantage respectively, delivered to LEO and other cislunar space facilities. While this estimate discounts the high capital costs of accessing lunar resources, such costs can be amortized at a rate low enough to maintain most of this profit potential.

Prinzton facility design criteria should favor the "low tech" approach of requiring the use of ample plant biomass to recycle carbon dioxide to fresh breathable oxygen and to otherwise "condition" the atmosphere inside the settlement. Indoor pollution, already a concern in contemporary terrestrial buildings using synthetic construction materials, will be a critical issue in a permanently enclosed biosphere which is essentially a closed system or at least one which has highly limited output leakage and input make-up in comparison to facilities of any size within Earth's biosphere.

Vegetation will also likely provide the "low tech" water filtration and purification for the closed-cycle hydrosphere envisioned, with pure water recovered by de-humidifiers from plant transpiration supplying drinking water at the "start" of the loop.

The evolution of lunar habitat design will require a transition from the initial "carry out and bring back" strategy of Shuttle missions, Space Stations like Mir and Freedom, and early lunar surface habitats, to one which introduces a sustainable largely closed-system biotechnology. The ultimate significance of this transition recognizes that life itself will begin to transform the man-habitable environment just as life has transformed Earth. Indeed, the design myopia most likely to prevail in our "Prinzton" scenario is the continuing focus on human requirements in the narrow sense of air, water, and nutritional needs.

The scale of Prinzton's ambitions for a large human population demands a recognition that the "best" biosphere for humans is also the most diversified; "best" here defined as the most stable, self-sustaining and diverse community of life forms possible. The physical security of any large colony will require food stocks which are diversified and not subject to catastrophic mono-crop failures. While the Moon is close enough to quickly resupply food stocks or to evacuate in the event of a "potato famine" type of bio-catastrophy, a Mars base would be highly vulnerable given the 26-month launch window spacing and long transit times.

Early high priorities for base development will be the creation of lunar soils from the raw material of the regolith, human wastes, and wastes from food production and processing. The micro-ecology of creating a growing soil bank for sustainable agricultural production will require planned early storage of biological wastes for their ultimate transformation into viable soils. Frozen storage in the lunar "shade" of lava tubes or high latitude rille and crater walls should initially be adequate. This process of storage and accumulation cannot continue indefinitely, however. These wastes will necessarily become the organic stocks of the new biosphere.

The capital equipment investment needed for this transformation of waste stock can be kept in bounds by employing the "M.U.S./C.L.E." strategy of Massive, Unitary, and Simple type elements that can be locally self-manufactured, married to Complex, Lightweight, and Electronic type elements that must be imported from Earth. Such a strategy minimizes the import burden needed to sustain the growing settlement, an incurred debt which has to be paid for with income-earning exports.

First, a sealed-atmosphere, temperature-controlled, humidity-controlled, and light-controlled environment with considerable volume will be needed. Prior experimentation with the development of viable lunar soils from lunar regolith simulant and biowastes will have shown whether a lunar soil micro-ecology can develop from these waste sources and whether or what additional seed stocks of specialized soil bacteria will be needed.

A prototype trial of this sort might be conducted in a near-sterile Antarctic environment, such as one of the "Dry Valleys" near McMurdo Sound, to gain engineering experience in conditioning cold soil-sheltered volumes into air-tight bio-spaces; and to validate the expected heating and lighting requirements, ingress/ egress provisions, etc. 'Regolith' pulverized from Antarctic rock and the accumulated bio-wastes from nearby Antarctic bases would provide the basic ingredients for creating viable soils.

Because many of the international participants in Antarctic research are also spacefaring nations, the creation of a simulated lunar (or Martian) biosphere in such a location could provide an interesting collaboration precedent. It would also supply economic data on both construction costs and logistic requirements as well as on the design requirements for storing and recycling the biological wastes generated by such bases. Because the "trashing" of the Antarctic environment is already apparent even with the relatively limited human intrusion there, this engineering prototype of a more eco-sensitive system will serve not only lunar habitat goals but also provide a transition to an environmental ethic requiring such Arctic or Antarctic bases to live downwind and downstream of themselves, something that settlers in the closed biospheres of the space frontier must do.

The difference between such polar prototype research sites and such potential sites as lunar lava tubes or rille-bottom enclosures is still considerable. Possibly some differences between Earth rock soils and lunar regolith, and certainly the available water and atmosphere, will make an Arctic or Antarctic experiment much simpler and far less costly. However, construction techniques at these temperatures, experience with equipment design, and the logistic experience with working bases and their crews in the collection, storage and development of suitable soils for sustainable agriculture would be exercises alone. The failures experienced by such a prototype biosphere could literally save the billions of dollars that would be wasted if serious design flaws are uncovered only after lunar failures occur. An Antarctic prototype installation will thus be sound risk management.

The selection of the type of biome(s) (eco-desert etc.) initially to be developed will also require closed system prototypes prior to any significant expansion of a lunar base. The strategy of Biosphere II at Oracle, Arizona in developing several diverse Biomes in close proximity, appears to this author to be a 'high stakes' gamble that homeostasis can be achieved and developed with a hybrid of existing natural biomes. A more conservative approach setting up just a temperate or tropical climate agricultural biome with an already known ecosystem of plants, animals, and insects, would seem to be a more simple initial step with a higher chance of stability.

The numeric modeling of each species' consumption, excretion, and impact on the other species sharing the biome, would enable the development of whatever fall-back chemical and/or mechanical component may be needed to insure full-cycle balances within lunar biospheres. A species data bank, appropriate monitoring technology, computer software, and operations experience, all need to be accumulated to develop confidence and sophistication in running a sustainable biosphere. This systems engineering problem is highly complicated and will require greater computing power to track the complex interactions between what will inevitably become hundreds, then thousands of species. The strategy of developing a replication of existing natural biomes and modeling them numerically should occur well before investment can be risked in a lunar application. Critical species serving as indicators of biospheric function (a miner's canary) must be identified.

Because Biosphere II in Arizona is essentially a proprietary enterprise, an independent critique of its outputs, systems engineering, and management technique is not likely to be generally available. This knowledge product may initially be affordable only to governments able to purchase this technology base. I am of the opinion that additional sealed biosphere prototypes both significantly smaller in scale than Biosphere II, and also considerably larger, will be needed to give confidence in the reliability of the biotechnology involved. This will need to follow a developmental progression from relatively simple and small biospheres to larger and more complex ones.

The outfitting of small Shuttle External Tank biosphere modules for initial lunar basing might progress to intact lava tubes. Such a tube could be sectioned off and sealed with needed environmental controls on the much larger scale of the Prinzton arcology of villages, horticultural and agricultural areas, and production facilities.

Economics will not be the only primary rational for biosphere development. Perhaps more importantly in the long run, the psychological comfort and stability of the human population will be critical. The stark beauty of the lunar landscape is unlikely to wear well on the human psyche. The "softened" environment created by plant and animal life will be an essential element of human expansion onto the Moon and elsewhere off the Earth. The "Garden of Eden" which mankind is rapidly destroying on Earth, will of necessity need to be reconstructed on the Moon. And tending this "garden" will be a major focus of human efforts there.

The type of high tech environment so familiar in space habitation scenarios usually have an an overwhelming industrial character to them, emphasizing machinery, rockets, mining equipment, and power generation equipment, etc. Prinzton's interior should more probably evoke a "hanging gardens" ambience than that of a(n) aircraft) "hangar". The very propensity of life to intrude into all areas of its ecosphere will no doubt produce many unforeseen and unforeseeable problems of maintenance and equipment failure. Vacuum seals, for example, should be designed of materials that do not serve well as dinner for anaerobic bacteria or other denizens of microbial reality.

The tenacious battles for species dominance in biosphere eco-niches are dynamic balances that must be carefully observed and monitored. These tasks of bio-maintenance and monitoring will initially be labor-intensive. The ratio of settlement population devoted to biotechnology including growing food, harvesting, packing, storing, preparation, and general bio-maintenance and monitoring will likely comprise 25% to 50% of personnel responsibilities. Thus the character of the settlement will be as much dominated by agriculture as by the other industries such as mining, oxygen-, metal-, glass-, and ceramic-production, transportation, and research and development efforts, etc.

The cost-per-pound economics of importing anything up out of the Earth's gravity well dictate an inevitable reliance on lunar-grown food stuffs just as they do for lunar-sourced fuel and building products. The curve of off-planet population growth will for the next century be more limited by lunar agricultural capacity than by other technology constraints. Neither Earth-based or Mars-based agriculture are likely to have economic significance outside their own respective gravity wells. Large scale sustainable biosphere construction in the asteroid belt will be possible only toward the end of this hundred year time frame given the probable stress on Martian and lunar development during that interval.

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Star*bound

Stardust Thou Art
To the Stars, Thou Shall Return!

New MMM Exclusive Series: Not "HOW?" But "WHERE TO?"

Disbelievers, contemptuous of popular talk of "travel" to the stars, abound. Indeed, the many hurdles *are* daunting! The enormous distances involved challenge comprehension. Total energy expenditures required compare with centuries of world energy consumption at current rates.

Yet the lure of the stars is "imprinted" on the very stuff that we are made of.

For, excepting hydrogen, which is mostly primordial, all the atoms of our bodies have been forged in the nuclear fires or violent death throes of stars that burned bright before our own Sun and its System coalesced from a cloud enriched with their collective ashes.

Many a book and article teases our faith that we will one day find a *way* to venture to other suns and the worlds we know must circle them. Little T has been written about where to head, and most of that we wish to challenge.

We start here on Earth, with a quiz and two articles, "Earth=Terra=Ga=Tellus" and "Hydro Tectonic Planets" we seek to define our own "home world" - our point of departure. "Planets Around Other Suns" looks at three ongoing searches for convincing proof that other solar systems do exist, *and* are common. [This last article is not included in this volume of MMM Classics: it has been superseded by events]

Would-be Starfarers Quiz

1. **Q.** What is the Sun's nearest stellar neighbor?
2. **Q.** How much further are Proxima and Alpha Centauri than the Moon? than Neptune?
3. **Q.** What is the closest star easiy visible to the naked eye from most of the United States?
4. **Q.** Is the Sun just an average star?
5. **Q.** What is the nearest Sun-like star?
6. **Q.** How far out must you go before it appears no brighter than other stars?
7. **Q.** Of all the naked eye stars, which is intrinsically the brightest?

Answers to Starfarers' Quiz

1. **A** Proxima Centauri, a small red M-type star, is just a little closer than the Alpha Centauri double sun of which it is a distant companion. This system lies 60° below the celestial equator, well below the horizon from most of the USA.
2. **A** 106 million times as far as the Moon, and 9,000 times as far as Neptune.
3. **A** Sirius is 8.7 light years distant, Procyon 11.3, Altair 16.6, Fomalhaut 23, and Vega 26 Light Years distant. With a small telescope, you can find Barnard's Star which is *only* 5.9 LY from here.
4. **A** Stars come bigger, brighter, and hotter; and they come smaller, dimmer, and cooler. But there are far, far more stars smaller than the Sun, than larger. About 4% of stars are solar-type, perhaps another 4% bigger and brighter, and 92% smaller. Ours is well above average, and that often heard put down is not honestly deserved. However, *most of the stars visible to the naked eye* are in fact bigger and brighter.
5. **A** Tau Ceti, just a bit smaller than the Sun is 12.8 LY away. Its spectrum is G0, a bit cooler and less massive than our G2 Sun. Alpha Centauri is actually a double star orbiting around its common center of mass. While the brighter of the pair is a GO, just a little hotter and more massive than the Sun, most astronomers consider binary stars to be unlikely or unfitting hosts for planets.
6. **A** About 14 light days or 2 light weeks out (80 times as far as Neptune) the Sun would still be as bright as the Full Moon for us. At 1.84 light years, the Sun would be only as bright as Sirius the brightest star to us. From 4.3 light years, the distance as Proxima and Alpha Centauri, the Sun would shine about as bright as Procyon, the 8th brightest star in our sky. The Sun would still be just visible to the naked eye in ultra-dark country skies 50 light years out.
7. **A** If Deneb and Rigel were as close to us as Alpha Centauri, they wouldd both be about as bright as the Full Moon, or some 10,000 times brighter than Sirius. To receive only as much sunlight as Earth does, a planet would have to orbit Deneb or Rigel more than 8 times farther out than Neptune from the Sun! In our corner of the Galaxy, F+Deneb, Rigel, and Canopus dominate all the space within 2,000 LY from here.

EARTH GA TERRA TELLUS

Should we Adopt a World-wide Name for Earth?

by Peter Kokh

To many people it would be an unimportant point. But one might hope that as mankind moves out into the Solar System, we would do so with a common agreed-upon name for our Home Planet.

"The Earth" - is the name we give it in ALL Indo-European languages. Whether we use the Germanic root ERD, the romance TER, the Slavic ZEML, the Hellenic GE, or Indic MAH, the reference to the solid earth = land beneath our feet is the same. Around the globe, names for our home planet use different sounds to express the same concept. Indeed, for other intelligent species on other worlds, the choice would be similar: earth=soil, sea or land+sea= shore. "Earth" seems to be a fully translatable name, a vocational-relational term, like 'parent'.

All the same, ought we not to agree on one internationally standard root-name to show pride in our ancestral home? What are the choices?

Many science-fiction writers dislike "Earth" because it is so provincially "English". This despite the fact that English, or Unilang as one language scholar now calls it, wherever it is not the first language, is the second or third.

By far the most common suggestion, taken for granted as future-fact by some science-fiction writers and many of their readers is the Latin for earth=soil=land, i.e., Terra. Unfortunately, astronomers have been anything but helpful, and have indeed been quite busy of late naming every newly discovered continent-like or highland-like region on other worlds mapped by our probes, "Terra This" and "Terra That" (Ishtar Terra and Aphrodite Terra are now the officirl names of the two continent-like highland areas on Venus). So the astronomical community has already unconscionably turned "terra" into a common noun even though other choices such as Creek "chora" were available, and even though versions of Terra are already in daily use for "Earth" by 600+ million users of Latin-sprung French (La Terre), Spanish (Tierra), Italian, Portuguese, and Rumanian.

We could yet outsmart the mischievous astronomers either by forming a new noun working back from the adjective terrestrial, e.g, Terrestra, or by using Terra as part of a compound name, as in Mariterra for Sea-Earth. After all, naming a planet whose surface is 3/4 ocean for the 1/4 that is land, does betray a certain chauvinistic bias and lack of appreciation for precisely what makes our planet so very special! Littora, Latin for "shores", would convey this same essential duality of our world. Or we might simply call it Oceanus and be done with it, although the diverse ways in which the latter would be pronounced around the world is a big drawback.

Considering the problem thirty years ago, my answer was to turn to the Roman goddess of the Earth, Tellus. The genitive of Tellus, from which the adjective is derived is Telluris, thus Tellurian. "Fellow Tellurians!" - it trips off the tongue so lightly! This beats terrestrial (from terra) which is already being commonized, both as 'mundane', and as referring to the solid-surfaced inner planets in general.

The Greek tribes used several variants of Ga, Gaia, Ge, Gea from whence our own Geo- root. What about one of these? First a phonetic observation: G followed by E is pronounced hard in some languages and soft in others. So GE, GEO, GEA, would not be mutually recognizable to speakers of diverse tongues. Further, the combinant geo- has lost its Earth-specificity via promiscuous application to the study of all solid-sufaced worlds by take-the-easy-way-out NASA geologists who have balked at using the more correct selenology for the Moon, areology for Mars, etc.

The ideal Creek-derived choice would have been Gaia with Gaian as the adjective, that is, until James Lovelock and Lynn Margulis preempted the word to signify Earth-Life in general (which is certainly a valuable achievement in Earth-awareness whether or not one agrees with their "Gaia Hypothesis" that Earth-Life or Gaia is an entity in its own right). The variant "Ga" is available, but sounds like baby-talk cut short.

Terrestra, Mariterra, and Littora, could be innovative solutions. But Tellus remains the one classic choice without liabilities. At the same time it is scarcely a household word. The plus side of that, is that specialists wearing horse blinders have yet to lazily and thoughtlessly genericize it. But how could such a new-to-the-public name be agreed upon the world-around? It would probably take an international campaign and a near unanimous United Nations resolution before Tellus would start showing up in science fiction novels, newspapers, and textbooks.

Besides picking a name for our planet to be shared by all forevermore, we might pick another name for Earth-*as*-transformed by the emerging human planet-wide civilization or technosphere, or for this "planetization" itself, even as "Gaia" has been pressed into service to refer to the evolving biosphere of Earth. We could coin "Anthropa" from the Greek word anthropos (= man, gender not specified) to serve this purpose.

Having a shared name for Earth, will help foster the co-operative pride we need to renew our planet and keep it "whole". Still, Earth, by any name, will ever be THE most beautiful world (and word!) known to her far-scattering children. Your comments are welcome. **< MMM >**

HYDRO TECTONIC PLANETS

What is an "Earth-Like Planet"?

by Peter Kokh

We've all seen the phrase "Earth-like Worlds" but just what does it mean? Different things to different people, of course. And that's because it is intrinsically imprecise, since there are so many varying definitions of just what the "essence of Earth" is. Some people use the term in contra-distinction to the gas giant planets like Jupiter and Saturn, Uranus and Neptune (which actually should be subdivided in two pairs, just as I have done, and not lumped together!) In this sense they use Earth-like to refer to solid-surface rocky silicate planets such as Mercury, Venus, Mars.

But for those who yearn for the promised era when humanity will venture beyond the Solar System and reach for the stars, "Earth-like" conjures up worlds of continents and oceans, sweet oxygen rich air, teeming plant and animal life. In contrast to the first example, this use of the term goes much too far in the other direction. For Earth itself would only have met this test of "Earth-like" in the last current fraction of its long history! We must get to the heart of the question to find an altogether different, less ambiguous, phrase.

Until the second half of the 20th century, it was the common belief that the continents formed in their present position. There was no attempt to explain why this continent had this shape, that one another. These were taken as factitious givens. True, many of the more inquisitive had wondered about the teasing near match of coastlines on both sides of the Atlantic. In 1905 the German meteorologist Alfred Wegner proposed a comprehensive picture of how the continents may have all been one and slowly drifted to their present scattered positions. But for lack of evidence, his theory was widely dismissed.

In of the most dramatic and exciting of scientific paradigm shifts since Darwin, a sudden flood of evidence from matching mineral deposits, fossils, and traces of paleomagnetism pouring in during the sixties, confronted unprepared scientists with the incontrovertible proof that Wegner was right in general, though he had many of the particulars wrong. It was not necessarily whole continents that drift, but great plates of oceanic crust on which the continents, or rather different sections of them, rest. Wegner's suggestion of continental drift gave way to modern "plate tectonics".

Evidently, unimaginably slow currents of molten rock deep below the surface nudge these plates this way and that, helped by repeated volcanic outpourings which rift continents asunder and push apart the pieces and the plates they ride upon. When something is pushed apart on a surface of set size, obviously somewhere else, something has to be squeezed together or give way in some other manner. And so most of the great mountain ranges on Earth have been raised by continental and sub-continental collisions taking millions of years. Hard to grasp at first! But India, once clearly part of the African landmass, crashing into the underside of Asia, has raised the Himalayas. The Appalachian and Atlas mountains were thrust up in a prior collision of North America and North Africa. Unthinkable? A few decades ago, but no more.

Continental collisions are not the only way pressure from spreading continents and plates is relieved. Often in a confrontation, one plate surrenders, so to speak, diving below the other whose edge rides up on top of it. The eastern Pacific ocean bottom is being thrust beneath the advancing west coasts of the two Americas. The coast-long deep ocean trench and ramparts of active volcanoes are results.

It is understandable then that geologists still bursting with the enthusiasm afforded by this new onrush of insights into the shape of present-day Earth, are alert for traces of plate-tectonics elsewhere. We DO see great faults and rift valleys on other worlds. Mars' Valles Marineris is an example - a gigantic 3000 mile long by 150 mi. wide equatorial canyon complex too often unfairly and inappropriately compared with Arizona's Grand Canyon instead of with the equally vast, if not more vast, ocean trenches on Earth, or better with Africa's great rift valley system including the Red Sea bottom.

We see signs of incipient, quickly stalled rifting elsewhere, even on the Moon. And as to continent-resembling features, there is the great Tharsis Uplift on Mars caused instead by eons-long continuous volcanism. And there are the two suspiciously continental elevations on Venus, Ishtar Terra near the north pole, and Aphrodite Terra along the equator. We've photographed volcanoes caught in the act of erupting on Io and Triton, and are being teased by a growing number of indirect indicators of current volcanic activity on Venus, such as lightning.

Magellan, the powerfully equipped synthetic aperture radar probe now on its way to Venus, will hopefully tell us the story of our sister planet's (nearly same size and mass as earth) past and present. If there are "ocean-basin" trenches along side "coastal" strings of volcanoes, that will reveal very much. This is unlikely, however. We already have enough lower-resolution radar imaging of Venus to know that there are fundamental differences between the structure of her "oceanic" basins and those of Earth's. It is no longer clear that now bone-dry Venus once had oceans that boiled away. If indeed an early ocean was present, it likely did not survive long enough to be a major role-player in the shaping of today's Venus.

Role-player? Yes, for it seems that water has acted as a lubricant in the incredibly slow movement of crustal plates and continents. The ocean bottom crust is saturated with water, and when it is thrust below the advancing edge of a continent, drags that compliment of water with it, down perhaps as far as 400 miles below the surface. Indeed we are likely to find that on any world where there has not been a significant hydrosphere (ocean), incipient tectonic activity has been an abortive self-snuffing episode. In contrast, Earth is a "HYDRO-tectonic" world!

Is this the "new and improved" definition we have been looking for? It could well be. It is the oceans *with* the internal heat of the planet that have shaped and continue to shape our world. Is this plate-tectonics necessary? Well without it, we would not have the rich mineral deposits that have fueled our technological crescendo. Nor might we BE in the first place. For it is not only the slate-clearing by periodic asteroidal impacts that has allowed stalled evolution to explore new manifestations of life, but also the continual separation and recombination of continental chunks. And without on-going renewal via mountain-building collisions, any original continents would long since have eroded away washing into the sea. Only "HYDRO-TECTONIC" worlds can be truly "Earth-like", in both the geological and biological senses of the term.

So when you next day-dream of joining some interstellar exploratory expedition, searching for "M-class planets" (to use a Star Trek term), you'll know exactly what it is you are looking for. Forget places like Tatooine and Arrakis (Dune). We need to look for worlds with enough ocean, but not too much, and with active plate-tectonics. Life will be more than probable on such worlds and should develop in a catastrophe-punctuated way similar to that which "Gaia" (the new name for Earth-Life as a living system) has experienced. The state in which we find such worlds will largely depend upon their age which can be estimated even from Earth via an in-depth study of its sun's spectrum and circum-galactic orbital characteristics.

Some HTW's will be impetuous raw young worlds still awaiting the quickening of life. Others will be dominated by early microbial life and show signs of oxygen-sweetening of the air. And there will be those on which has appeared the metazoan multi-cellular life that has dominated our own planet the past 600 million years (but an eighth of our total history). And there will be some on which the plate-tectonic engine has slowly ground to a halt, bringing any such world to the final eon-long chapter of its history. Eventually its sun would shine on a world gone the way of Atlantis as the last continental remnants, no longer being renewed, erode away and wash into the thickening sea-brine.

Can Hydro-Tectonic planets be detected from Earth? Yes and no. The next generation of space telescopes after Hubble, might be able to detect planets the size of ours, and as close to their parent suns as ours. Next we can look for the characteristic signatures of oxygen and methane. These gases can only appear on a hydro-tectonic world on which life has already arisen and evolved to the point where it can transform an original carbon dioxide atmosphere.

It would be interesting to equip a deep space probe with instruments to detect such a characteristic signature, and see how far out from the Sun, we can clearly detect Earth and tell what kind of world it is. The proposed TAU mission would go out one Thousand Astronomical Units, a thousand times as far from the Sun as Earth's orbit, not quite six light-days. (Neptune is only 30 AU, 4 lt hrs away.) It is the intention to use the advantage of such distance to greatly refine our parallax-based knowledge of star distances. An HT-signature device (HTS) would make a great bus-mate for TAU.

While it is unlikely that life can arise in a fresh start except on a hydro-tectonic world, it should be transplantable to other less friendly locales. And good transplant locations may be much more numerous. But that's another story! **<MMM>**

[For an excellent, very readable, and well-illustrated book on Plate Tectonics, might we recommend "The Restless Earth" by Nigel Calder, Viking Press 1972, SBN 670-59530-6]

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RAMADAS

"YARD" AND WORKSITE CANOPIES FOR LUNAR OUTPOSTS

[Artwork on Cover Page by Dan Moynihan]
by Peter Kokh

Examine a picture of an Antarctic Base, and you will see a cluster of main buildings awash in an unplanned, unkempt cluttering of fuel tanks, stockpiles of supplies, new equipment not yet installed and old equipment already retired, trash dumps and so on. Base architects have a tradition of leaving to afterthought the siting of necessary external paraphernalia, the things that make base operations work. Nor is such an unsightly hodgepodge of land use expediencies the only result. Since the realities of base operations were not taken into account, as only individual structures rather than integral functioning of the base as a whole - or likely patterns of growth and evolution - received attention, it is an inevitable result that such sloppy installations function rather less efficiently and less safely than they might.

The sketches available of various Moon Base designs, be they the product of NASA think tanks or of outside sources, share this ivory tower penchant for neglecting patterns of likely land use in the immediate vicinity, in the front and back "yards" of principal base structures.

It is inevitable in any Lunar Base operations scenario, that an appreciable portion of routine "out-vac" EVA activity will take place in a few concentrated areas, especially the immediate vicinity of the Base itself, and of its component structures and facilities. There should be a very thorough effort to identify and categorize the types of activities involved and the intensity of use of these "yard" spaces.

Current planning and design provisions make no distinction between those EVA activities on the base doorstep and those spacesuits-required activities at some distance from camp. However, the relatively high intensity of usage of selected close-in areas for storage, staging, repairs, or other repetitive outdoors housekeeping tasks, offers us an opportunity to make such routine activities both safer and easier.

By designing lightweight, modular, and easily deployable work canopies or "ramadas" strong enough to hold a few centimeters of regolith insulation blown on top, Lunar Base architects can provide built-in cosmic ray, ultraviolet, and micrometeorite protection for these high use activity areas. ["Ramada" is a Spanish word common throughout our treeless plains and desert areas for the shade-providing shelters at roadside rest stops.] Providing ramadas will allow those working in such sheltered areas, while still exposed to vacuum, to wear lightweight more comfortable pressure suits. Under such improved conditions, those working outdoors could put in more hours with significantly less fatigue, with lessened vulnerability to random micometeorites, and with reduced cumulative radiation exposure.

Such ramadas might be attached to various base structures themselves, in an analogy to awnings and lean-to sheds, or stand free but adjacent to them. They could cover an area continuously or make use of overlapping panels to allow some reflected sunlight to ricochet between top and bottom surfaces into the working spaces below.

Those whose assignments take them beyond such protected yard areas will still require the heavier more cumbersome hardsuits. For some such cases it may be possible to design mobile or "redeployable" ramadas to use at temporary sites of heavy outdoor activity such as can be expected in the field at prospecting sites or with the time-consuming installation of scientific equipment, solar arrays etc.

Kevlar fabric slung over frames of aluminum poles, all brought from Earth, could form the earliest ramadas. In the light "sixthweight" of the Moon, such fabric would be more than strong enough to support an overburden-load of several inches of loose regolith shielding. But as Lunar manufacturing develops, glass-glass composite panels covering glass-glass composite lightweight space-frames and pylons, all manufactured on site, could fairly early on become the standard means of providing safe workspaces sheltered from the avoidable "elements" that buffet the exposed Lunar surface.

We began this article by pointing to a general unsightliness that has come to be characteristic of this country's Antarctic bases. While a strategy of careful management of high-use yard space, including the use of ramadas, would clean up much of this clutter, on the Moon as well as in Antarctica, that is certainly not its principal merit. The unsightliness, as much as it grates, is but a symptom of the deeper ill of lackadaisical management of base operations. It betrays an attitude which is of one piece with that same carelessness which breeds accidents, both mechanical and human.

Most will accept that we cannot tolerate the expense of mismanagement on the Moon. Part of good base management will consist in providing the safest possible routine working conditions. The added cost of bringing along the materials to erect ramadas over those highest-use outdoor areas around the base will be well justified.

Next time you see an artist's depiction of a Moon Base, whether it comes from NASA, the Lunar & Planetary Institute, SSI or Eagle Engineering, ask yourself "what's wrong with this picture?" If the grounds look neat and uncluttered all without ramadas, the rendering will clearly be more akin to science fantasy than science fact.

If ramadas are essential facilities for Lunar bases, no matter how absent from base concepts currently in vogue, then a national competition to come up with some good design options will be in order. Such a competition should have three categories: (1) for first generation bases, the most economical use of imported material; per square meter sheltered; (2) for next generation bases, early practical use of building-materials made on site; and (3) mobile and/or redeployable ramadas for use in the field. Prize money to entice participation could come from traditional sources such as aerospace contractors, but also from materials industries who wanted to promote the use of their products e.g. Aluminum, Kevlar, Glass, and Steel, or from construction firms. **< MMM >**

[This article is an expansion of an abstract sent to AIAA in response to its solicitation of ideas for Moon/Mars Missions & Bases. Thanks to Michael J. Mackowski of St. Louis Space Frontier Soc. for alerting MMM to this opportunity.]

FLARE SHEDS

BUTT-SAVERS IN THE OUT-VAC

by Peter Kokh

[For a related article, see "WEATHER", MMM # 6 JUN 87, republished in MMM Classic #1]

The Sun doer not rotate integrally as would a solid-surfaced body. We can clock its rotation by watching sunspots, slightly cooler areas that look black only in comparison, slowly transit from west to east over a two week period. Spots nearer the equator are carried across the face more quickly than those near the poles, marking one rotation in about 25 days, compared to 28-some nearer the poles, and as slow as 36 days at the poles themselves.

Keep in mind that sunspots, occurring in pairs, mark places where intense magnetic fields project from the surface, and it becomes clear that the Sun's overall magnetic field must become ever more tortuously twisted and kinked with each differential rotation until the pattern finally can be maintained no more. Such a crescendo is eleven years a-building. At the end of the cycle, the magnetic polarity reverses, so that the overall pattern repeats every 22 years.

Solar flares might be seen as the bursting of solar-energy "dams" maintained by great magnetic forces within these sun spots. As the dam bursts, a flood-surge of energetic particles heads out from the Sun at an appreciable fraction of the speed of light. Light takes 8 1/3 minutes to span the distance between the Sun and Earth (= 93 million miles = 150 million km = 1 Astronomical Unit) so when a flare is spotted (if anyone, anything, is watching!) we have only a few moments before the deadly storm hits. For the associated X-rays advancing at light-speed, the only warning possible is a means of predicting such eruptions.

On Earth we are sheltered from the full fury of such lethal solar flares first by the Van Allen radiation belts maintained by the Earth's own magnetic field, and then by our atmospheric blanket. Nonetheless, enough energy some times gets through to disrupt radio communications for hours, even cause massive power outages by inducing current surges in transformers and transmission lines. Though the inconvenience for us is mild in our protected cocoon, and while they cause spectacularly beautiful auroras, we can be grateful that flare seasons come 11 years apart.

The most intense portion of a flare onslaught can be over in just minutes or last a few hours. Beyond the Van Allen Belts, the need for shelter is immediately pressing. Flares can occur in clusters and single flares can have the energy of hundreds of millions of hydrogen bombs. The direction the torrent takes is random, depending on the location of the source spot on the solar surface.

Unless we are to limit our activities on the Moon, and throughout space in general, to quiet-Sun years, two things must receive priority attention:

1. developing a Flare Early Warning system
2. developing a network of storm shelters within reach.

The first need is touched on briefly in the earlier MMM article cited above. The second requires multiple strategies. On route to Mars, we can put all the fuel and cargo and equipment sunward of the passenger cabin (the "P.O.S.H." strategy: Passengers Outfacing, Sunfacing Hold). Coming home with empty holds and tanks presents a more stubborn problem. But here we want to highlight situations on the lunar surface.

Lunar bases, habitats, factories, and whole settlements will be sufficiently protected by the same 3-4 meter thick overburden of loose or bagged regolith shielding that shelters them from cosmic rays and micro-meteorites. Surface activities in the immediate neighborhood of such sites should present no problem even in high flare season. But in time an outpost or settlement will be joined by others as the lunar beachhead transforms into a more "world-like" SET of human places. How do we protect those traveling between such protected sites?

Surface vehicles can be designed *top-heavy* with batteries, fuel cells, cargo and other heavy equipment on top - that's sound practice anyway, and the center of gravity problem can be handled by longer wheelbases and wider tracks - no problem when the cost of real-estate and right-of-ways is moot. While these measures will reduce routine exposure to other hazards, they may be less than adequate during solar flares, especially when the Sun is at a low angle over the horizon. Ports in the storm will be welcome.

Open ended north-south facing quonset-type shells covered with a couple meters of soil, situated at intervals along established routes, could harbor a number of vehicle emergencies. How close will we need to put them? Obviously that depends on things we can't pin down as yet. First, how much early warning time can we expect (= how much time do we have to take cover) and how much ground can vehicles traverse while the clock is ticking. We'll want a reassuring margin of safety.

The need to reach shelter with time to spare and the relative expense of erecting such flare sheds could put a real premium on vehicle swiftness, well-graded roadways, or both. Excursions off-the-beaten track in "shedless areas" may be limited to emergencies, during flare season. The alternative is to travel during the 2-week-long lunar nightspan in the "lee" of any storms. This may work to confine lunar "rural" outposts along established routes between major settlements or to provide storm-cellar-equipped vehicles to service the less frequented routes.

Over time, if traffic increases warrant it, some of these flare sheds could grow into more full-featured facilities: emergency communications, automatic self-replenishing liquid oxygen depots, drop-off points for fuel cell water to be automatically electolyzed by solar power back into liquid oxygen, and hydrogen, for fuel cells of other vehicles, hoist-equipped repair ports, unstaffed hostel-type bedroom space and so on. Eventually, some such oases might even become the first humble beginnings of whole new towns.

The way lunar development proceeds, from the placement of outposts, the design of vehicles, and the preparation of roadways - much that will shape the unique character and feel of the Lunar Frontier - will trace back to this need to cope with the occasional deadly solar flare. Storms do have their usefulness! - **< MMM >**

SOLAR FRINGE BENEFITS
OF INTENSE LUNAR SUNSHINE

by Peter Kokh

Most of the pluses of cloud-free access to the undiminished strength of sunlight on the Moon are too obvious to need listing. The key words: heat, electric power, light, photosynthesis. On several occasions we've also mentioned a solar benefit easily overlooked: the considerable endowment of gases adsorbed to regolith fines (pulverized upper soil blanket) from four eons (billions of years) of bombardment by the weak but incessant Solar Wind. ["Helium-3" & "Gas Scavenger" in MMM # 23 Mar '89 - republished in MMM Classics #3]

In this writer's philosophy, anything whatsoever has only assets. *Apparent* liabilities are just that, appearances things have when one's outlook isn't right: when our knowledge is incomplete, our assessment immature, our attitude is not quite "game."

The usually cited liabilities of the Sun's unbridled stellar fury as it lashes the Moon are these: intense raw ultraviolet radiation and "fortunately rare" deadly blizzards of ionized particles traveling just below the speed of light, originating in solar flares. Our bias suspects both of being assets in disguise.

Might we not quit brooding about the dangers of UV exposure for naked flesh and plant matter, long enough to investigate whether or not this area of the solar spectrum has any potential as an industrial tool? Surely there is incentive enough to pursue the question!

For there is a seemingly endless litany of chemical and industrial processes routinely used on Earth, often with unwelcome side-effects, that do not lend themselves at all to lunar application. Either they involve materials that are too expensive to make available on the Moon, or they would soon be lethal in the unforgiving, tightly closed, quickly cycling mini biospheres we'll need to cradle our existence on our barren neighbor. Given these strictures an our activities, discovery of more Moon-appropriate forms of processing would be rather welcome.

On Earth we're addicted to "improving" and/or "disguising" surfaces of various materials with coatings and/or chemical treatments that would be taboo for one reason or another on the Moon. Looking for alternatives, we might ask what would be the effect an various alloys, types of glass and ceramics etc. of various lengths of exposure to full-spectrum ultraviolet? We have no idea, but shouldn't someone endeavor to find out? (Full-spectrum UV is not yet naturally available on Earth but give the Ozone hole time to grow!)

By the use of suitable resists or stencil overlays, could some types of glass and some alloys be etched and/or textured? If so, could this become an art and craft method as well as a manufacturing process? If satisfactory fiberglass papers or scrim can be developed, could we print-impreg-nate this with oxides that would "develop" given raw-UV exposure?

Perhaps these ideas are farfetched idle musings of an armchair chemist. But we would be sorely disillusioned if some happily serendipitous results didn't come out of an honestly far-ranging set of experiments. Will the tests on the LDEF (Long Duration Exposure Facility) finally retrieved this past December by the Space shuttle Columbia, carry useful clues? Undoubtedly six years of raw-UV exposure has done its work on the LDEF trays, but it may be difficult, if possible at all, to sort out these various effects from the smothering and masking corrosion expected from orbit-altitude atomic oxygen.

We have already suggested [MMM # 31 Dec '89 "Ventures of the Rille People" Part V.B. Hydro-electric Storage System?] that the well known germicidal and bacter-icidal effects of raw-UV be put to work in waste water treatment. (Glass filters out UV but quartz panes let it pass through.) Raw ultraviolet may also play a role in food processing and preparation. Its tissue-destroying ability might be harnessed as a fine-honed tool in various other ways such as "sun"-printing cotton, leather, and jewelry woods. Raw ultraviolet can be reproduced in Earthside labs and, with proper safety precautions, the fun of exploring such possibilities can begin now.

With so much of today's sophisticated processing techniques unsuitable for use in lunar conditions, the settler economy will need all the help it can get. Investi-gating the effects of raw full-spectrum ultraviolet on the likely stable of lunar materials would be a good start.

The opportunity to put solar flares to work will be quite sporadic. But there will be ways to turn that liability into an asset also. **< MMM >**

SUN HELIOS SOL RA COPERNICA

SHOULD "THE SUN" HAVE A NAME?

by Peter Kokh

While many could perhaps care less, it seems appropriate to this writer at least, that all peoples of Earth share one common name for their life-giving star. This is hardly the case.

"The Sun" - is one single word into which we put two quite distinct references. First, "the Sun" is our name for a parti-cular star, the one we orbit. Second, "The Sun" is a vocational relationship which makes this star special: it centers a planetary system, which it bathes with warmth and life-giving energy.

In the first sense, "the Sun" is very unique, *our* very own star. In the second sense, it is a relationship of fostering paternity (and the origin of the idea of "the Demiurge" with semi-divine co-responsibility for our existence). And this relationship is most likely not unique. Any star with planets is, for them, "the Sun". 'Sun', then is a word a lot like 'Father' and 'Mother', i.e. a title rather than a name.

So long as mankind's horizons and its expectations of spreading domain do not overflow the Solar-System-of-our-Origin, this dual function word serves reasonably well. But as we consider the eventual out-migration forming a human diaspora that could include any number of "solar systems", the need to come up with a non-generic name for *our* Sun becomes increasingly relevant.

Almost all science fiction writers who have been faced with the problem, have taken to referring to *our* Sun as 'Sol'. This choice has two burdensome liabili-ties. First, "***Sol***" is, once more, "the Sun" in another language, ancient Latin. Second, the deri-vative, "solar", will very likely be used generically of all planetary systems, and of all star-planet relationships. In this light, "Sol" makes a rather poor and unhappy choice.

Other than Latin, we could borrow from the other classic language of antiquity. In Greek, the Sun is Helios. And again, the derivative, "helio-", is also already in use in a general sense (e.g. heliostats) and is likely to go with us to the stars as yet another generic. One way around this particular problem is to coin slightly altered adjectives to refer to out particular parent-star and its realm. For example, we could say Solaric System when we are referring to our own, and use solar systems in the generic. I can't think of a plausible parallel for helio- serving the same specific function, but I'm sure Greek-adepts could coin one. Then it becomes a matter of public education.

What about the ancient Greco-Roman god of the sun, ***Apollo***? Alas, the word has existing currency (manned lunar program of the sixties) making it a confusing choice.

Already well known, simple, and easily internationalized, is "***Ra***", name of the ancient Egyptian sun god once revered in Heliopolis. But a case could be made for "***Bast***", another Egyptian deity who represented "the life-giving power of sunlight". Also lees known is the ancient Sanskrit "***Ravi***" and Hindu "***Surya***".

Quite a different solution would be to give our own Sun a proper name adapted from that of a figure in world history who played some especially significant role in our understanding of the Sun's place in the scheme of things. My vote would go not to any recent solar astronomer but to Copernicus, the first of our species to teach *effectively* that the Sun, not our Earth, is the center of our system. Now his name is already given to a very prominent lunar nearside crater. One way to avoid confusion would be to use a variant form of his name. Instead of the original harsh sounding Polish "Kupernik", we could use a feminine form of the common Latinization i.e. "***Copernica***". Admittedly this flies in the face of the almost universal chauvinist convention of using only masculine names for the Sun, with feminine ones reserved for Earth, i.e. the Earth-Mother/Sky-Father theme of folk myths.

Perhaps you would like to suggest yet another choice? My own preference? I'd say "Copernica" and "Ra", in that order, over the other options listed above. But it's a wide open question! **< MMM >**

OCEANIDS

EUROPA-LIKE WORLDS MAY ABOUND

by Peter Kokh

Ever since the romantic pre-space-age vision of a planet-wide ocean on Venus was so cruelly burst by the radar detection of surface temperatures there in the 900 °F range, and since our probes showed that the atmosphere on Mars was too thin to allow liquid water to subsist on its surface, we have had a growing appreciation of our water-laden home planet for the very special oasis which it is. But the revised popular notion that, in all the Solar System, Earth alone has appreciable reserves of liquid water, is mistaken.

Another Water World?

On their fleeting passes through the Jovian system, the four Pioneer and Voyager probes revealed an ice-crusted Europa, with a surface that has been aptly described as "smooth as a billiard ball". Absent are any crater relics of the earlier epoch of wholesale bombardment by debris left over from planet-formation, an ordeal apparently experience in common by all the planets and their moons. Europa's brilliant white crust is crisscrossed by narrow brownish streaks that show no topographic relief (height or depth). Global elevation differences do not much exceed a token hundred meters or so.

Apparently, the ice crust of this moon is thin enough to fracture under internal pressure from time to time, letting a water-brine of some sort erupt out onto the surface, quickly freezing the fracture shut. Europa, it seems, has an ocean! Water and vacuum do not socialize. But ice and vacuum get along quite well. Thus a thick enough self-derived icy "firmament" can contain an ocean just as effectively as a thick atmosphere.

However, some source of internal heat is needed to keep the ice crust from thickening until that's all there is. Europa, a little smaller than the Moon (1942 miles versus 2160 miles in diameter), is hardly big enough either to have long-retained any residual heat of formation, or to have undergone sufficient internal heating from radioactive materials in the rocky silicate crust that probably underlines its ocean - we know Europa's mass, hence its density, and can argue from that. Of the four great Jovian moons, Europa is the second closest-in, and that's near enough to provide continuous heating from the tidal stress that characterizes its location deep down the throat of Jupiter's massive gravity well.

Europa: more water than Earth?

The guesstimates I've seen are that the ice crust is no more than 2-3 miles thick and that the globe-enveloping ocean below could be 60 miles deep. Even considering Europa's smaller size, 1/4 th the diameter and 1/16 th the surface area of Earth, that still amounts to 1.8 times as many cubic miles of water as in all Earth's oceans (back-of-the-envelope calculation). Any hypothetical Europans would be amused, if not chagrined, to read of Earth's boast to be *the* "water planet"!

A proper name for Europa's Ocean? In ancient mythology, Rhadamanthus was the son of Europa by Jupiter. So ***The Rhadamanthic*** would seem an especially appropriate choice.

A Mind Probe of Europa's Ocean

Europa and its ocean supplied the supporting theme of a major motion picture: Arthur C. Clarke's "2010". What might the conditions in this ocean be like? We would expect it to be devoid of dissolved oxygen. But any gases vented by submarine volcanoes, a plausible feature, once they reached a certain saturation point in the water, may keep collecting in gas pockets below the ice, eventually building up enough pressure to fracture it in the manner our probes have observed. There could also be some dissolved salts, not from any sediments washed down from eroding protruding continents, of course, but from ash vented by these same conjectured submarine volcanoes.

Deep Ocean Life on Europa?

Given the light Moon-like gravity, even at some sixty miles down, the water pressure would be only half that in the Marianas Trench in our own Western Pacific. Exciting? Conjure up story plots? Hold on! Enter another discovery 400 million miles sunward, down home in Earth's own ocean depths. Scientists have found thriving teeming oases of ocean-bottom life huddling around deep sulfur-rich hot water vents on the mid-ocean ridges. Here in the absence of appreciable dissolved oxygen, hitherto totally unsuspected well-diversified colonies of life-forms evidently descended from familiar varieties - yet strangely, grotesquely, and beautifully evolved - live out secluded lives feasting on their exotic dietary bonanza, in a darkness whose totality is sometimes punctuated by the orange glow of quickly cooling erupting lava. We had once thought that all food chains, must begin with photosynthesis. Evidently, hot sulfur-rich mineral-laden water jets provide nourishment and energy enough upon which to base whole independent ecosystems.

[For an amply-illustrated early account, see National Geographic.November 1979]

It is *the safer assumption* that life could not originate in Europa's ocean - or that it could not have gotten much further than sulfur eating bacteria. On Earth, even if the sulfur-eating organisms at the bottom of the hot-vent food chains are native to such sites, the diverse multicellular metazoan creatures such as the tube worms we now find there, are surely cousins to long-familiar varieties and co-descended from ancestors that had evolved in oxygen-rich, photo-plankton fed ecosystems in much shallower seas. Yet it seems equally plausible that we might someday successfully transplant some denizens of our own ocean bottom vent colonies there, at the bottom of the Rhadamanthic. We could then hang around for some centuries to watch their progress from stations on the ice-crust-firmament above, using telemetry and teleoperated benthic probes.

We need to take a look-see

Where is the imagination of our planetary scientists that they have not yet brainstormed a mission to dispatch a drill-equipped probe to Europa? Well, drilling through some miles of ice is far more ambitious - as remote robotic missions go - than anything we've attempted to date, even skin-pricking comet penetrators. This is a mission for the next century, one that will generate a lot of suspense and expectation. Now that we have found relics of ancient, probably now extinct, native microbial life on Mars, shall we someday find evidence of existing microbial life in Europa's ocean? How far and how diversely will it have evolved?

Are there other water moons?

Some have suggested that Europa's larger siblings, Ganymede and Callisto, with 3.3 and 2.4 times as much surface area respectively, also may harbor vast oceans under their dirty ice crusts. But it is clear from the near saturation incidence of slumped craters on their surfaces that the ice crust on these moons must be substantially thicker, and that as a consequence, water from below is far less likely to work its way up. Both moons are too far removed from Jupiter to benefit from tidally-induced heating. So it seems more likely that any oceans there are long since frozen through.

Saturn’s close-in Enceladus also sports a smooth bright icy surface apparently regenerated in recent times. Again, tidal heating and water venting are suspect. Whether this much smaller world, only 310 miles across, still has a mini-sea under the visible surface is something else.

Life-friendly "E-Class" Planets May Vastly Outnumber "M-Class" Worlds

Whatever the case for Ganymede, Callisto, and Enceladus, in general, the conditions for the formation and maintenance of Europa-like moon worlds seem rather easy to meet in the vicinity of gas giant planets. And gas giants should be quite commonplace throughout the galaxy. It will matter little if the Jove-like primary of the candidate moon does not orbit a sun-like star. Might they not even circle rogue gas giants and isolated brown dwarfs in the sunless interstellar reaches? (Brown dwarfs are dud wanna-be stars with not quite enough mass to trigger or sustain nuclear ignition and thus become true "stars". The jury is still out on whether they are relatively rare, or far more abundant than all other star types.)

[As of 4/'00, similar sub-ice oceans are strongly suspected on both Jupiter's moon Callisto, and Pluto's moon Charon. - PK]

As Europa is one of a class of very special worlds that we might search for elsewhere we'll need a generic name for them. One possibility is "oceanids", pronounced oh-SEE-a-nids. In mythology, the oceanids were daughters of Oceanus and Tethys. But "europids" (yoo-ROH-pids) would also work, taking their name from the first of the class to be discovered.

What really gets the juices flowing is the possibility that Europa-like worlds are far more common out there than Earth-like ones, outnumbering them by perhaps a thousandfold, or more. We ought to make it a top priority in the next century of two to see what we can do with Europa - exercising all due environmental caution, of course. Farming the sub-glacial oceans of such moons could be an alternate ticket to the universe, one which many a star-faring civilization has adopted for its main thrust.

What would a humanoid culture in a Europa-type setting be like? How would it develop? Would they live like the fictional survivors of some sunken Atlantis - subject of several science fiction films and TV episodes - in pressure resistant glass and metal "bubbles" within which they breathe air - and live, work, and play much as we do? Hey, if you're looking for a fresh twist for your science fiction novel, why not brainstorm such a "stranger in a strange land" type of culture? What you come up with might be a truer caricature of the galactic "beyond-the-cradle mainstream" than is the world and civilization into which we've all been born. **< MMM >**

MMM #38 - September 1990

Conepts of Regolith Primage

PRIMAGE

A “Do or Die” Key to Lunar Industrial-Agricultural Success

by Peter Kokh

The pre-tilling of the Moon

Through eons of meteorite bombardment, lunar soils have been extensively "gardened" or turned over vertically, and even mixed horizontally - up to half the surface materials in any given area is the import of splashout (impact ejecta) from areas nearby and distant alike. On Earth, mineral-based industries have been able to take advantage of enriched and concentrated deposits - a result of eons of geological processes peculiar to our planet. While undoubtedly somewhat more favorable concentrations of a few minerals do occur on the Moon (homogenization provided by bombardment not being 100% thorough), in general lunar settlers will have no choice but to make do with deposits we would shun as "uneconomic".

While the Moon is richly endowed, in a gross sense, the lunar economy will have the much more difficult job of separating out or beneficiating the desirable minerals prior to processing. No one should imagine that just any system of lunar mining-based economy would guarantee success.

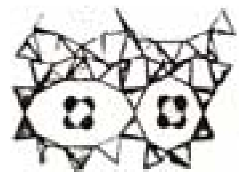
In "Gas Scavenger" [MMM # 23 p.4 March 1989 - republished in MMM Classics #3] we pointed out that if we *religiously* extracted the pure iron fines and all the Solar Wind deposited gases from *any and all* regolith that we had to move or handle *anyway*, we would then accumulate potentially valuable reserves, *at low cost*, that could be one principal means of diversifying the settlement economy. We *have to* move regolith in excavating for shelters, in covering them with shielding, in grading roadways, and in providing raw materials to ore processing facilities. Iron fine removal (by magnet) and gas extraction (by heat) capabilities should be an integral part of ALL regolith-moving equipment, we counseled.

Agricultural Needs

Let's carry the argument further. Apparently, some of the things that worry lunar agriculture researchers most, are actually characteristics of 'gross' lunar regolith easily changed in the handling process. After all, settlers won't be erecting domes over undisturbed lunar regolith, then attempt to farm this raw soil. We will be building pressurized agricultural modules of whatever volume - and *then, moving* regolith *from* the outside *into* the prepared beds within.

Researchers worry that the 15-20% fraction of regolith which is ultra-fine powder of less than 0.25 mm grain size, fine to medium silt, will clog soil pores leading to water-logged soil. In the Moon's light 'sixthweight', water will percolate through the soil more slowly; thus we will want somewhat coarser soil than is ideal on Earth. In the course of bringing regolith-soil in from the outside, this fine silt can be removed by vibration-sieving or by 'winnowing'. As a bonus, this unwanted fine silt may have a higher content of adsorbed Solar Wind gases; also it may be easier to process in some ways (glass?, ceramics? etc,) than less refined 'as-is' regolith.

The 75% ideal medium-sand-through-coarse-silt 1.0-0.25 mm fraction is next. A 3rd sieve removes larger agglutinate glass nodules which can then be transformed-into zeolites by mild hydrothermal processing [150^o C, 0.3 MPa, 76 h]. Zeolites are hydrated silicates of aluminum with alkali metals (K, Na) and cavity-rich crystal lattice structure. They can be used as catalysts, adsorption



media for gas separation, insulation, and molecular sieves. And *added back into the "soil",* they will enhance mineral ion transport to plant roots, especially in early 'immature' soils not yet fully colo-nized by micro-organisms nor laden with organic matter. How to provide for suffi-cient mineral ion transport in regolith-derived soils is thus another needless worry on the part of researchers. [In view of these possibilities, I am rather critical of the value of lunar agriculture experiments that use any lunar simulants formulated on the unexamined presupposi-tion that we will be stuck with using crude raw regolith.]

The remnant after this last sieving operation would be larger rocks (aggregates and breccias) that could serve well as gravel fill, for lunar concrete. So, just by including this multi-step vibra-sieving operation in our "Regolith-mover", we will have (1) enormously enhanced the chances of success for lunar agriculture; (2-5) started businesses in molecular sieves, gas-separation, catalysts, and insulation; (6) supply the highly refined material needed for processing; and (7) supply coarser material for 'lunarcrete' mix.

A third worry of the Lun-Ag people is potentially toxic levels of chromium and of nickel in regolith-derived soil. Their concern is perhaps more justified with chromium, as observed nickel concentrations are possibly tolerable. *How* we could make use of regolith pre-handling opportunities *To extract* a significant fraction of the Chromium-containing minerals (e.g. some spinels) is a nice *challenge* for the chemical-engineering types among our readers. How about it?

A Tool for Many Needs

Now that's quite a work load for our everyday Lunar 'Lith-Mover! Iron fines; Solar Wind gases; silt for processing; Ag-grade soil; zeolite feed stocks (glasses) for agriculture filtration and insulation; gravel for lunacrete; chromium ores. We can obtain all these in the very handling of regolith, *prior to all other forms of processing* - including oxygen-extraction and glass-glass composites (Glax) production. For these collective *First Fruits*, I propose the term "Primage." [Most dictionaries define this term solely as a safe-handling bribe paid by a shipper to ship's captain and crew. But as a suggestive precedent, the O.E.D. also has: “the amount of water carried off suspended in the steam from a boiler” (about 3%)]

A Primaging 'Lith-Mover

Going through all the bother of careful regolith-primage, much like scraping and sanding the loose paint before repainting, will seem to most a thankless and unwelcome ritual. There will be a strong temptation to dismiss the need. But the settlement that adopts primaging as a transcendental imperative, will have a significant head start towards economic diversification and self-sufficiency.

Primaging could be the well-spring both of prosperous lunar industry and of productive lunar agriculture. Developing a practical, simple and rugged "Primaging 'Lith-Mover" should then be among our very highest priorities. **< MMM >**

LUnar
National
Agricultural
eXperiment
corporation

Logo by Fred Fleischmann and Peter Kokh
Report by Peter Kokh

The Birth of LUNAX

There is a new kid on the block in the effort to pre-develop the repertory of technologies that will someday enable us to establish the sizable self-supporting settlements on the Moon that will at last make mankind a multi-world species. Some people, it is true, still labor under the assumption that such a grand goal is merely a matter of money, hardware, and national will. Leaving them to their comforting illusions, some of us in the Lunar Reclamation Society Inc., [M.L.R.S. incorporated under this name July 30th] have quietly started to peck away at the still growing load of homework that will really be necessary, in the hopes of finding ways to contribute which will *test* the limits of our collective talents.

In the process of working on our entry in NSS' Space Habitat Design Competition (1989) Lunar Base Category, alerted by a "whoa!" from collaborator Joe Suszynski of Chicago, the new Milwaukee Space Tech & Rec team identified one serious potential show-stopper. Unlike a smaller outpost probably powered by a nuclear reactor, a larger settlement may be economically strapped to use that energy available to it in as efficient a way as possible - at least until prosperity from trade reached a point where the settlers could burn up the ergs in a more customary carefree American style! To get the community's vital food crops through the fourteen day long lunar nightspan with the same amount of light provided 'free' by the Sun during dayspan, would take a power generation capacity several times as large at that needed to take care of all the settlement's other needs such as construction, industry, transportation, air/water circulation and treatment, etc.

A Need to Experiment

Realizing that any settlement's success might in large part depend on knowing how little and/or how infrequently their plants needed a light-fix during the nightspan to coast until the next dayspan growth period - and still produce an acceptable harvest - our SSI support group, Milwaukee Space Studies Team (MiSST) put together a small pamphlet aimed at enlisting home hobby gardeners. "Guidelines for Experiments in Lunar Agriculture" is slowly getting more exposure and sparking lots of interest. However, interest is painless (i.e. cheap). Taking the trouble to carefully perform these lighting experiments in one's basement or garage on a plant species of one's choice seems to be another matter. Simply put, the data from our rag tag green thumb army of enthused participants is not flooding in. We will need *lots* of data on *lots* of different plants. Even though it will not be possible to rigorously control experiment conditions, a lot of data might yet provide a good enough signal to noise ratio to enable us to pick out *significant* results from spurious ones. But how do we get that flood of data?

[Early Soviet experiments showed that if the plants are simply chilled to a few degrees above freezing, they would survive two weeks of darkness just fine, springing back during the alternating two weeks of light-feast to produce good yield. Eric Drexler, while still in high school, performed a similar closet vs. refrigerator type experiment with corroborating results. But even though temperatures *would* fall off once the Sun had set, at a rate that depended on the effectiveness of the insulation and the amount of the thermal mass within the farming unit, it might still take a considerable energy expenditure to induce the proper chill level, all at once, then maintain it - even if heat pumps were used to dump the heat into a eutectic salt or water reservoir from which it could be recovered near the end of nightspan, when heat was most needed. Chilling the crops may be one part of the answer - but we still need to know *all our options*!]

Getting Organized

To the rescue, MLRS member-at-large David A. Dunlop of Green Bay, Wisconsin; I first met Dave at the '89 Neptune/Triton Voyager Encounter party at the Fox Valley Planetarium in Menasha a year ago. Dave became quite enthused-about our Prinzton Lunar Base design study. That fall, he started making the long drive down to Milwaukee twice a month to take part in our brainstorming sessions on a possible book to expand upon our Prinzton study. These sessions would often last into the wee a.m. hours, after having adjourned from the Central Library's Old Board Room to the nearby I-Hop, or some all other 24-hour eatery.

When we took up the proposed chapter on Agriculture and the Biosphere, Dave became riveted on the challenge of the quite limited extent and rudimentary level of appropriate experience and know-how available. Not only do we need to know all our lighting options, we need to know how to transform *sterile* Soil that has *never* known air or water into a medium that can *sustain* its crop yield *season after season*, not just once. We needed to determine what plants, and what microorganisms, would work together in a very limited ecosystem. We needed to know a lot of things. And in point of fact, all we really know now is that we need to know one heck of a lot more!

Late one evening, Dave's call interrupted Star Trek TNG with a challenge. We need lots of data and it simply isn't coming in from individuals. Why not organize the "Lunar Nightspan Hardiness" Experiment and perhaps some other suitable agricultural experiments and then *enlist High School Science Teachers*, with the hope of getting more data, and data of better quality? Not being one to come up with an idea and then go hide, Dave immediately started networking, beginning with fellow Green Bay NSS member Neil Walker, high school science teacher. Through Neil, Dave got in touch with Ed Mueller in Neenah, Secretary of the Wisconsin Society of High School Science Teachers. Further calls uncovered considerable interest, even enthusiasm, for the idea.

Next Dave started calling select professional researchers in the field, with NASA connections, to solicit their ideas and comments. This was 'rough work', especially considering that NASA's efforts have concentrated on the food supply and biosphere needs of very limited small outposts - *unrealistic models* for what we proposed to do. Most of the Pros seemed to take it for granted that we'd have all the lighting energy we wanted on the Moon, and that crops would be raised in isolated and automated phone booth size pressure chambers. Once Dave backed up and explained to them our much more ambitious perspective, they showed a heightened interest, curiosity, and willingness to give advice and assistance.

Now that we began to feel confident that we had found a promising approach, the task became one of organizing. On June 23rd Dave and I drove up to Sturgeon Bay in Wisconsin's beautiful Door County, to meet his friend, attorney and Chicago restaurateur, Albert H. Beaver Jr. There in his office we drew up papers for a new non-profit corporation, with the three of us as Directors, to pursue the effort to involve schools in those areas of Lunar Agricultural Research wherein the present rudimentary level of our knowledge still leaves room for meaningful school-level contributions.

A Magic Setting

Al owns a private resort, the ***Chateau Hutter***, along the Bay shore, nine miles north of Sturgeon Bay, and we decided to use this "ideal" facility to host an “Invitational Workshop” for a *short list* of high school science teachers and professional researchers (some of these by tele- conferencing) to carefully define an initial set of experiments, and establish an Advisory Board and Reporting System to keep the process going.

The 1st LUNAX™ Workshop-Conference was set for Tuesday thru Thursday, August 21st-23rd. Because it was necessary to limit attendance to a dozen or so in order to insure results, and because this brash initiative was not guaranteed success, we decided not to publicize the event outside the chapter. LUNAX I is now history.

Thanks to a truly magic mix of individuals of varied talent, endless enthusiasm and deep conviction, we succeeded in defining our goals and designing an initial 2-track set of experiments. The Lunar Nightspan Hardiness Experiment (here we are looking for the limits of crop failure) will begin with a practice run using Wisconsin Fast Plants' Brassica rape, able to go from seed to maturity in 28 days, and used in thousands of schools across the country. We will then seek to zero in on the nightspan hardiness of a wide variety of food and fiber plants that may make attractive candidates for the Lunar Biosphere.

We also prepared guidelines for an open-ended multi-year Lunar Soil Evolution Experiment using MINNESOTA LUNAR SIMULANT (here we are looking to find strategies for success). Three additional experiment tracks are in process of development, each of them aimed at supplying knowledge we do not now have, but which we will need if a “Return To The Moon to Stay” is to be successful.

Prospects

We are off to a propitious start and it's time to let the cat out of the bag. We will be field-testing our initial LUNAX experiment package in about a dozen schools in Wisconsin. The next step is a major presentation at the annual convention of Wisconsin Science Teachers in Manitowoc, next April 19-20th, before spreading participation throughout the country and abroad.

Our purpose will not be just to teach already known space science. Rather, by reaching out through the hitherto untapped resource of H.S. Biology and Ag-science Teachers, we offer kids a "unique opportunity" to contribute brand new science of vital importance.

Agreeing to serve on LUNAX' Board of Science Advisors: Mel R. Oleson of Boeing Aerospace, Seattle; Gary G. Lake, Clarke & Associates, Technical Director Wisconsin Fast Plants, UW-Madison (an expatriate of Brisbane, Queensland); C. William Easterwood, the U. of Florida in Gainesville (and formerly at the LAND, Epcot Center); and Paul W. Weiblen (of Minnesota Lunar Simulants) U. of Minnesota Space Science Center, Minneapolis. LUNAX will most likely be based in Crew Bay, Wisconsin.

Wisconsin high schools anxious to premier the LUNAX Experiment Package include Chippewa Falls (McDowell), Green Bay (East, Preble) Madison (Memorial, West), Milwaukee (Bayview, Rufus King), Neenah (Shattuck), Racine (Park), and Waukesha. We can expect to pick up more schools as word of this unique science opportunity spreads.

LUNAX' immediate task will be to gain experience with the initial experiment package worked out at Chateau Hutter, and to guide the follow up research, while continuing to define complementary experiment directions. A modest school registration fee system will allow results to be gathered and analyzed, new experiment projects to be developed, and a newsletter (Harvest Moon) to be published. Individual hobby-gardeners and armchair fans outside the school system will be able to participate in or follow LUNAX progress. MiSST's pioneer work will be continued by LUNAX.

We also hope to tap talent at the community college level. We have a fine start here at Lac Court Oreilles Community College in Hayward.

The challenge facing Lunar National Agricultural Experiment Corporation is an exciting one. While the work to be done is frighteningly enormous, the team gathered at Chateau Hutter begins with the confidence of being on the right track. MMM will keep readers informed with updates on our progress. We welcome this first addition to Lunar Reclamation Society Inc.'s new family of roll-up-the-sleeves partnerships. **< MMM >**

Many Thanks

to

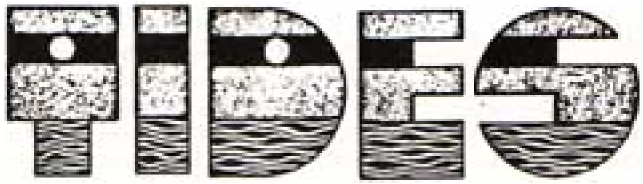
Arthur P. Smith

for keying in the articles from MMM issues #21-40, which previously existed on Commodore 64 floppies, no longer readable.

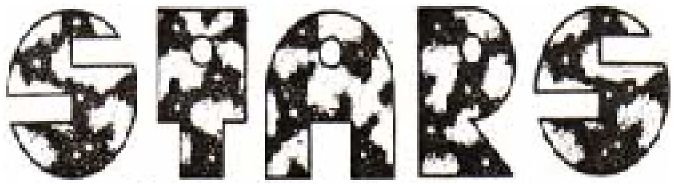
Without his assistance, these two volumes of MMM Classics, #s 3 & 4, would have been postponed indefinitely.

[Star*bound Series Cont.]

OF TIDES



AND STARS



by Peter Kokh

Gut Feelings

I am forever grateful for having learned from the American philosopher William James that our temperament influences reason more than most of us care to admit.

When it comes to the cosmic place of mankind, it is temperament that predisposes some to give more weight to considerations that suggest we are unique,

and others to give credence to considerations that suggest just the opposite.

Some people have an inner need, based neither on reason nor evidence, to hold that we are alone in the immensity of space and time.

Is a large moon necessary for life to emerge?

Often cited as argument, is the unexpectedly large size of the Earth's natural satellite, the Moon. By all indications, a planet of Earth's size and proximity to its star, ought to have no moon at all, or a very small one at best.

What has this to do with the presence of life on this planet? The Moon causes tides, and thus creates and maintains tidal pools in near-shore depressions, places where the proto-life soup of amino acids and other pre-organic molecules could stew and brew. In contrast, such molecules would be so diluted in the ocean at large that they might never interact sufficiently to get something really interesting going. And so, their argument goes, as most Earth-like planets would not be as fortunate in possessing such a large moon, they would not form tidal pools needed as incubators.

This argument, articulated by some respected people, is nonetheless "in bad faith". First of all, the Sun also raises tides, and while it is true that solar tides are much lower and weaker than lunar ones [the ratio is about 1 : 2 1/2], if the height of the tide is great enough not to be masked by common wave action, just how high it may be is quite irrelevant. The important thing is the availability of near-shore depressions with an erosion-resistant lip within reach of tide crest. Even if tide height were important, solar tides in up-flow cul-de-sacs like the Bay of Fundy are higher than the highest lunar tides in most other places. Continental placement vis-a-vis ocean currents is the major *co*-determinant of actual tide heights. All it need take is just one tidal pool to successfully concentrate and simmer a proto-organlc soup of the right recipe.

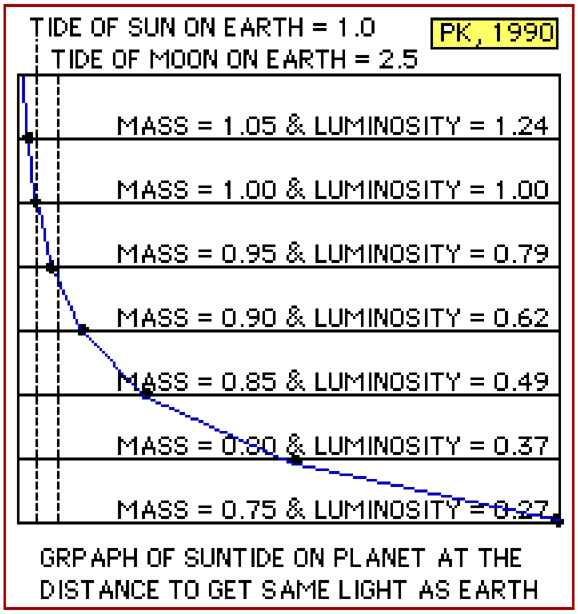
But let us accept, for the sake of argument that Earth may be unique in possessing such a disproportionately large moon (actually, Charon, in comparison with Pluto, about which it orbits, is proportionately much larger and closer). Let us also accept, for argument's sake, that tides relatively as weak as those raised by the Sun are insufficient to do the job, That still does not rigorously lead to the conclusion that life is unlikely to arise elsewhere in the universe even on planets that are otherwise of the right size, composition, and proximity to their central star.

Squelching the argument

Stars smaller and dimmer than ours will have eco-zones (in which the amount of light and heat per square meter is favorable to life) that are closer-in to their central star. *But since* a star's luminosity varies as the 4.5 power of its mass, and as tidal force increases inversely with the *cube* of the distance (*not* the square!), stars only 'slightly' dimmer than ours will raise tide *significantly* higher on any planets situated in their eco-zones to receive the same amount of light and heat as does Earth.

Tau Ceti, the most promising planetary host in the solar neighborhood (12.8 Lt yrs distant) has a 0.74 solar luminosity, and thus an eco-zone radius of 0.74 AU [1 AU = 1 Earth-Sun distance], but with 0.935 solar mass. It would hence raise tides of 2.01 mean solar value at an earth-like light/heat distance. And this approximates the present tides raised on Earth by the Moon.

Epsilon Eridani, also near and solar is smaller, dimmer. It must raise still higher tides on any earth-like world it harbors. And so on. Stars less luminous still might tidally arrest the rotation of any equi-lighted planets. See Graph:



Even a star of the same luminosity as the Sun or not too much brighter, can raise tides of lunar-like proportions *seasonally* (and that's all that is necessary) on a properly positioned *moonless* planet, *if* that planet has a sufficiently eccentric orbit. For example, if Earth had no major satellite but had an orbital eccentricity of 0.26 (e.g. swinging in as close to the Sun as Venus, and out half way to Mars), it would experience tides of lunar intensity for a few weeks each year near perihelion.

The upshot is this: even conceding the rather crucial role of tidal pools in the successful origination of life on Earth, and even conceding that Earth may be uniquely blessed with a major satellite large enough and close enough to raise tides significantly higher than those raised by the Sun, *It does not at all follow that the rise of life must be rare,* let alone a once-in-a-universe, once-in-all-time occurrence. Au contraire, the strong plausibility of equally effective and considerably more common "great tide" scenarios becomes a major argument for the opposite hypothesis - that life must he common. If ever we do reach the stars, we will find *life-laden* worlds! **< MMM >**

Polders, A Space Colony Model

by Marcia W. Buxton*

* a Cultural Anthropologist & founder of Northwest O5 Society Chapter (now Seattle L5/1) in June 1996

From the beginning of human civilization families have made sacrifices for their children and for future generations. In order for human civilization to continue it seems self evident that families must eventually move into space and become a spacefaring people. An interesting parallel can be drawn between the familial movement into space colonies and the Renaissance development of the Polder System in the low countries of Europe. Each is truly an artificially created environment.

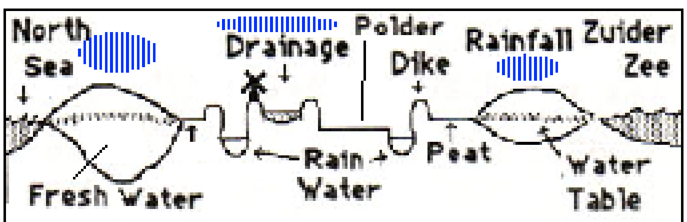
"A polder is a piece of land won from the sea of inland water and is constantly defended from it thereafter," explains Paul Wagret in *Polderlands*. Beginning in the 11th Century along the Northern Coast of Europe families labored to painstakingly force the sea to relinquish land in order to provide farm land for their progeny. These brave men and women worked hard to provide future land not for themselves but for their children and their children's children. In the same way serious thought must be given by all families today to look to space colonies to provide a better life for their future generations.

The family structure as it had developed by the 11th Century, in what is now the Netherlands, decreed that at a husband's death his widow received half his wealth excluding his land. All his farm land went to his eldest son and the remaining wealth was divided among the brothers. This custom allowed for a large enough area of farm land to be passed from one generation to another to sustain at least the eldest son. Daughters were generally expected to marry or enter convents to pray, teach, copy manuscripts and care for the sick. The remaining sons frequently were prepared to enter guilds to become expert weavers or other sorts of craftsmen. The center of cloth production was the city of Antwerp. Other sons might choose the monastic life.

In France, wealthy Lords would often grant monks the right to the marsh land on the edges of their properties provided that the monks endeavored to successfully drain the land for pastures and maintain them as polders. This "reclaimed" land was theirs henceforth. Here they constructed their religious buildings including stone towers which could be used as shelters in times of floods by the people living in the low lands. Mont St. Michel is an example.

In the areas of Friesland, Zealand, and Flanders much of the land was a brackish peat bog bounded on the North by the Sea (illustration below). As the population expanded, the digging of peat to be dried and used as fuel became necessary. The word "polder" may derive from the Flemish word poelen, meaning "to dig out". This digging was done in conjunction with the digging of ditches for the drainage of the brackish water into the sea. This lowered the water table and the people learned that when these [newly] created dry areas were planted in clover and desalinated with natural rainwater, eventually this area became land where cattle could graze and much later hops, hemp, flax, coleseed, rapeseed, cereals, and finally flowers could be grown successfully. This often became the land of second and later sons.

In order to aid the drainage of the low lands, canals needed to be constructed. Dikes using woven willow twigs and burnt clay bricks were built systematically to keep the brackish water from returning to the hard earned low crop lands. The area is often six feet below sea level. Great care needed to be taken not to dig for peat too near the dikes which might be weakened causing catastrophe.



Hydrological Cross Section of Low Countries

By the 13th Century primitive windmills and lifting dredger buckets were established along these "highways" of brackish water. Younger sons became inheritors of the early windmills. Bridges, locks, and paths were built along the canals to aid the families in fetching drinking water which often could only be obtained by going a considerable distance to an area where rainwater collected sufficiently for fresh water wells.

At the end of the 15th Century due to religious persecution in other countries many immigrants, particularly Anabaptists and Mennonites who refused to bear arms, fled to the low countries. Here the ruling class, perhaps because some of their ancestors had been among the Crusaders in the Holy Lands and had opened up early trade routes and welcomed new ideas and foreigners, respected these people who were willing to work so very hard to drain fields and maintain the polders. And they, as other polder workers, were exempted from military service and payment of land taxes. These immigrants were allowed to organize their own schools and churches.

The development of the canal and polder system was not without many real catastrophes. There was often great destruction but always followed by rebuilding. The canals also began to serve other purposes and small barges were used to develop an efficient system of primitive commerce, dispersing beer, wine and salt. With the beginning of commerce came certain restrictions. Members of the ruling class, usually people owning large amounts of land but who lived in the towns and villages, began to demand tribute for the use of the canals near the villages.

The continuing need to dig for peat for fuel which enhanced the reclamation of the low lands, the emergence of the windmills, the building of locks, and the slowly developing system of commerce encouraged the establishment of "high water authorities" and water boards. Voting rights depended upon ownership of farm land. Among the peoples of Utrecht, Netherland, Zeeland, and Flanders there were to become in the 14th Century the hoogheemraad schappen or high water authorities and [they were] responsible only to the governments. At the local level these Waterschappen came to serve the function as a court of law.

Just as the marsh lands were reclaimed from the sea with embankments, with increases in population attention needed to be paid to reinforcing the coastal sand dunes along the North Sea. Wagret describes a polder dike as being perhaps 40 meters in width, but a main sea dike may reach 80 to 100 meters in width. The ebb and flow of the tidal currents along the sea coast sometimes caused erosion.

Jan de Vries, in The Dutch Rural Economy in the Golden Age, remarks that rural districts were prohibited from brewing, spinning, weaving, or ship building but that skippers of barges passing villages were required to dock, unload their cargo and allow their goods to be offered. In 1575 there were elaborate plans made which are reminiscent of the early plans and dreams in the 1970's of the L5 Society for Gerard O'Neill's High Frontier. His "Bernal Spheres" concept, housing 10,000 people, were to be nearly a mile in circumference and rotate to provide gravity comparable to that of Earth. The L5 Society proposed building such habitats by the end of the twentieth century from lunar materials to provide living space for workers and their families in a space manufacturing complex producing, among other things, satellite solar power stations to supply cheap, clean power to Earth.

Immigrants to Bernal Spheres were to develop a better life for themselves and for future generations. It may not have been by digging peat out of low lying bogs and creating drainage ditches, but by using materials from the Moon, colonies would be created and solar energy would be utilized to grow food in a closed system, and eventually there would be trees, streams, attractive housing, and a peaceful environment for future generations. One space colony would act as a stepping stone to the building of others.

The Haarlemmer Meer Book of 1575, by Jan Adriaanszoon, describes an elaborate plan to build 160 windmills and to build extensive canals to drain a major lake area. Like the L5 Society's early dream it was not developed immediately but finally with the invention of the steam engine the project became a reality in 1852.

By 1607 the Leeghwater's Beemster drainage project using 43 windmills created 17,500 acres of usable acreage. Some of the money necessary to finance this project came from the highly successful Amsterdam merchants of the East India Company, trading primarily spices, sugar, coffee and tea. Land owners were encouraged to grow livestock to provide large amounts of butter, cheese, and livestock that could be exported abroad. Near Amsterdam by 1649, six villages combined efforts to provide a dairy for the nearby city, using their farm lands for that purpose.

Capitalists beginning in 1612 developed ambitious large scale pear digging organizations. Plots were carefully laid out as were canals and locks where settlers dug the peat and later were able to claim the soil as homesteads [illustration below].

Overhead View of Possible Early Polder

According to de Vries, "dike maintenance was an obligation divided among the villages that benefited from it." A land user was responsible for a specific segment and the Waterschappen supervised the system.

Windmill operators took on growing importance and were expected to keep the polders dry throughout the winter. In 1574 an 8 sided windmill was worth 3,500 gulder and the salary of a mill operator was 100 gulder plus a supply of candles in order to work at night! Rapeseed became a frequent polder crop and oil-pressing windmills in Northern areas often were kept busy the entire year. Windmills were also used for sawing wood [harvested] from carefully tended groves of trees.

de Vries writes that "the monastic lands yearly yielded several hundred thousand gulder for the support of education, health and welfare. Women played a very important role in the life of the religious community. Churches played a major part in the communities providing some education, but literacy in the majority remained low. Nevertheless five universities were established.

Canals became of increasing importance and interconnected the major villages and cities. Barging guilds were formed and established regular service between major cities. Frank E. Haggett sites that by the mid 1650's 80,000 acres had been reclaimed form the sea. The farmers taxed themselves hundreds of thousands of gulder yearly to improve the quality of their soil. Sea shells were ground up and used for fertilizer. Everywhere farm structures and homes were enlarged or rebuilt. Commerce along the canals flourished.

In 1667 there was a proposal to polder an inland sea, the Zuider Zee (See Figure 3). Hendrik Stevin developed the idea of closing off the incoming tide with sluice gates but allowing the ebbing tides to flow into the sea. Eventually the fresh water would replace the salt water sea. (The project was actually begun in 1927 and the first crops harvested in 1933 with 175,000 acres eventually reclaimed.)

By 1798 there were over 3,000 local Waterschappen and a central Waterstaat was created to fight against major floods. "The state set itself up as a protector against floods, the hereditary enemy of the country. The Waterstaat undertook works too large for small groups, collected data, coordinated hydrological observations and drew up maps. According to Wagret, 577,905 acres, or fourteen percent of what is now the Netherlands, had been reclaimed from the sea. The cost of the recla2mation always exceeded the actual value of the land first brought into cultivation - only future generations were to be the true beneficiaries.

A worthy cliche, "God made the Earth, except Holland, which the Dutchmen made for themselves." Might that we, with God's help, break free of Earth and build the Universe for ourselves. **< MMM >**

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Note: It is in the above sense that the word “Reclamation” is used in “LRS.”

MMM #39 - October 1990

Saving Money on Food in Space Prior and Future Progress

by Peter Kokh

$400/oz or the price of gold these days, works out to $6400/lb. The way we have been making anti-progress in slashing the cost per pound of getting anything to orbit, much less from there all the way to a soft landing on the Moon, that would be a very optimistic ball-park guesstimate of just the 'freight-added' cost of *anything* upported from the Earth to early lunar outposts.

Everyone recognizes the importance of finding ways for early settlers to self-manufacture the more massive items they will need, out of whatever materials they can process from moondust. But often I hear "Oh, we could afford to import this or that - it hardly weighs anything!" Hey, just remember, it will cost more than gold!

Thus it is not surprising that it seems self-evident to most people that it will be an urgent priority for lunar outpost volunteers, and the settlers that someday will follow, to grow their own food - 'it would cost too much to haul it up from Earth.' But this common wisdom is a bit simplistic, nonetheless. Let's take a look at some very real virtual savings in food costs already realized even though we still do bring all food up from Earth - in one form or another.

Already we freeze-dry most foods destined for space, saving all the weight of the associated water. To rehydrate the food, we use water manufactured in space as a by-product of the orbiter chemical fuel cell energy system which runs on hydrogen and oxygen. Yes, we bring these bottled gases up from Earth - but now, we are not 'also' bringing up extra water just for food and drink.

bottled	fuel		freeze	ready
$H_2 + O_2$	]]]]]]]>	H_2O +	dried	= to eat
gases	cell		items	FOOD

Check the labels on freeze-dried foods packed for campers at the local outfitters supply store and you will be surprised to see that water accounts for as much as 65-80% of the weight of ready-to-eat meals. Now that's real savings!

When the first returnees establish our beachhead outpost on some 'magnificently desolate' lunar plain, even before their prototype food-growing unit brings in its maiden harvest of vegetables, they can realize another 89% breakthrough in food and drink costs as soon as they start using oxygen 'squeezed' from the moon rocks to make up that associated water of hydration. At this stage, we will be upporting only hydrogen and freeze dried foods.

So, when our nifty little 'agricule' starts spitting out real fresh food we save the total cost of upporting freeze dried food, right? Not quite! All we save by this loving garden-tending labor of raising our own up-home food supply is another 53% of what we can get our regolith-soil to supply.

Typical composition of oven-dry biomass from wheat, for example, is:

48.0% Oxygen
2.0% Calcium
0.8% Magnesium
0.01% Iron

all of which we can get from our make-do soil, plus some

2.7% Potassium
0.8% Sulfur
0.6% Phosphorous

of which we can get perhaps half from the regolith. The rest must be upported from Earth: 36% Carbon 6% Hydrogen, 3% Nitrogen, and perhaps half of the Potassium, Sulfur, and Phosphorous.

Settlers will strive to mitigate this burden by vigorously recycling their waste biomass and anything else of organic content, by withdrawing from the productive biosphere as little organic material as possible (i.e. no wood for furniture or other items, where substitution is possible), and by carefully engineering all entry and exit systems to conserve nitrogen-rich air supplies. [See "Liquid Air-locks" in MMM # 17 July '88 p3 - republished in MMM Classics #2]

How could we make inroads into this stubborn balance? This still onerous import burden will drive settlement policy. As much as 2/3 rds of the upport transportation fuel cost can be saved by bringing in the needed Carbon, Nitrogen, and Hydrogen as liquid methane and ammonia processed on Phobos and/or Deimos, the companion mini moons of Mars. The capital costs of installing such a production capacity could easily be amortized as the lunar population grows. The profits realized at Mars could defray the costs of opening up the Martian frontier. A doubly attractive strategy!

There is one way, however, that lunar settlements might become totally self-sufficient in food. And that is by supplying all their Carbon, Nitrogen, and Hydrogen needs as byproducts of extensive Heliium-3 mining operations to supply Earth's voracious energy appetite. Of these, in comparison to lunar demand, the least abundant by far is Nitrogen - which will be *the* limiting factor on settlement growth, mostly because of the high volumes needed as a buffer gas in air. Hopefully, profits from Helium-3 exports will allow the settlers to pay the import price of as much extra Nitrogen as they'd like.

What we have said about food is equally valid for usually forgotten but vitally important byproducts of prospective lunar agriculture: fiber (cotton, linen, flax), oils, natural biodegradable dye stuffs, cosmetics and soaps, and other eco-friendly household products. Of these, fiber for clothing, toweling, bedding, and furnishings will likely receive the earliest priority.

Saving money on the Moon by defraying avoidable upports from Earth is only one part of the Story. Lunar agriculture even in the early era when all Carbon, Nitrogen, and Hydrogen must be imported, has the potential to earn badly needed export income for the settlement. For Luna-grown food, simply for the Oxygen savings it realizes, will be deliverable to low Earth orbit and other space locations at a decided price advantage over fresh food brought up from Earth. Ditto for fabrics and anything else incorporating lunar Oxygen. Early production of oxygen is then the key to everything else, and all the fuss about lunar agriculture presupposes this development.

The space frontier economy will be a complex hierarchy of supplies and demands. We hope you can appreciate the great potential for diversification ahead - *if we do our homework now!* **< MMM >**

Moon Mining
& Common Eco-Sense

by Peter Kokh

The multi-thousand-year-long record of human mining activities on our home planet will surely be enough to convince even the most bribe-prone galactic bureaucrat to deny us required permits to extend such esource extraction efforts off-planet. In default of such red tape, it is left up to us to judge and police ourselves.

With mines come huge ugly piles of useless barren tailings and scarred landscapes slow to heal, streams poisoned with acid run-off, and legions of workers with dust-racked lungs. The record gives pause to those considering opening up pristine eco-vulnerable Antarctica for development of its legendary mineral wealth. Should it not also give pause to those who look with such high expectations to the plains and rolling highlands of our serene gray neighbor, the Moon?

The salient points to remember are these:

(1) The Moon's mineral endowment has been minimally differentiated or locally concentrated and is thus distributed rather homogeneously, by Earth comparisons, in ores that are extremely poor by our standards. There will be no reason to fight over deposits or jump another's claim.

(2) There is no reason to believe that richer deposits lie buried deep beneath the already pulverized regolith-blanket that covers the entire surface to a depth of some 2-5 meters. In effect, countless ancient meteorites by their bombardment have already "pre-mined" the surface for us. There is no need for open pit mining.

(3) As to what does lie deeper, the central peaks of the larger craters represent upthrusted material from several kilometers below - sample and source enough should we need it. There will be no need to deep tunnel the Moon.

(4) In the absence of atmosphere, any and all dust 'kicked-up' by our various activities, has nothing to suspend it above the surface, and is quickly purged from the near-surface vacuum by the Moon's light but effective 1/6th gravity.

(5) Tailings, the unwanted residue after resource extraction, will be visibly indistinguishable from the source material. Tailing mounds will blend in with the moonscape, and if preferable, can be raked back over the surface. The only clue to an area's having been mined will be a telltale absence Of minor craterlets. Tailings should usually be minimal, nonetheless, since more than one resource will be extracted leaving little more than the proverbial squeal of the pig.

[See "Tailings" in MMM # 23 March '89 - republished in MMM Classics #3]

(6) Fluids and gases used in the extraction process such as water, hydrogen, hydrofluoric acid, chlorine etc. must be brought from Earth at great expense. So resource extraction cannot possibly be accomplished economically unless ways are found to recover and recycle these reagents almost totally (read 99%). There will be no mass leachate drainage into the environment.

(7) Even in the case of accidental spills of reagent leachings, there is no lunar ground water to pollute or spread the problem. Spills will remain localized and it will be an economic imperative to recover as much as possible.

(8) Miners, if you can call them that, will not be breathing atmosphere in contact with the regolith they are processing. Health concerns will instead focus on minimizing accidents and exposure to cosmic rays and rare solar flares.

(9) As to housekeeping activities of miners themselves in their shielded habitat warrens, they too must recycle and conserve religiously [see "Saving Money on food in Space"-elsewhere in this issue]. They will assuredly be acutely aware that living immediately "downwind" and "downstream" of themselves in cradling mini-biospheres leaves scant room for eco-carelessness.

As long as private enterprise - carrying the baggage of the almighty "bottom line" - is the agent in question, you can rest assured that sheer economic necessity will work mightily to prevent 'eco-nonsense' on the Moon. The real danger would come with government leadership and its deferrable accountability.

When you hear or read someone express alarm at prospects for developing the Moon, remember these points. A good response with this as with any challenge: "That's just what I used to think - until I looked into the matter further!" **< MMM >**

Moon Mining
& Engineering Realities

by Peter Kokh

In an article in the June 1990 issue of the Engineering and Mining Journal with the title "Moon"Mining: should we boldly mine where no one has ever mined before?" Earl C. Herkenhoff, P.E. raises several points about the very logic of moon-mining. His tone is blatantly hostile.

The writer's principal point is that (to his knowledge) our survey of the Moon's mineral wealth is so incomplete that it is highly premature to be discussing what we can - or cannot extract from it, and certainly premature to be spending hard scarce cash on studies as to how to go about doing it. Our response is that while admittedly our mineralogical survey is far from complete, the wide equatorial swath 'read' by orbiting gamma ray spectrometers on board Apollo Command Modules the last three missions, coupled with the six widely scattered diverse surface sites actually sampled by our astronauts and the three additional sites sampled by the automated Soviet sample-retrieving missions, gives us high confidence that what we've seen and sampled is representative of the Moon at large.

Herkenhoff insults NASA geologists and their carefully supervised astronaut proxies when he speaks scornfully of "only a few pounds of

- √ “grab samples” “snatched” from the surface of the Moon
- √ at only “a tiny spot” on the surface where the landing craft was set down."

It's clear that the writer hasn't gone even the first mile in trying to objectively understand what we were trying to accomplish during Apollo.

The granted exception to this is the absence of sampling and orbital readings near the lunar poles leaves open the possibility that perma-shade cold traps in deep near-pole craters may contain volatile resources which have been ruled out elsewhere. On this very point, vis-a-vis the possibility of finding water, the writer betrays his shallow study of published lunar findings by speculating that more thorough prospecting might find hydrates as fixed water in igneous rocks. To the contrary, we are now quite certain that the Moon formed hot and dry and that none of its volcanoes or fissures spouted any steam and that its great lava outpourings were also quite dry.

The writer shoots his respectability in the foot when on the one hand he complains that our exploration has not been thorough enough, and on the other he states correctly that the Moon is 'unlikely to contain minerals that have been concentrated by magmatic segregation'. When he states that 'it is a safe bet that most minerals are complex silicates' he isn't telling us any thing that we don't already know quite well.

He also shows the shallowness of his science background when he doubts out loud how we can be so sure that Solar-Wind-derived Helium-3 is more than a local quirk in the few tiny soil samples studied. Surely there is no mechanism by which the Solar Wind could have deposited its largess in anything BUT an indiscriminate way!

Herkenhoff complains that established mining companies have not been consulted about mining methods - after he has already slipped and told us that they wouldn't dream of trying to extract anything useful from such miserably low grade ores. "Even on Earth, process hydrometallurgists would flinch at such an assignment." In point of fact, established companies have been too busy getting wealthy off of Earth's much richer ores to have bothered to accumulate any know-how that might apply to the situation facing us on the Moon. What would be the point in listening to those whose predictable broken-record message is "it can't be done"? We have no choice but to seek out rebels willing to try something new.

He points to the difficulty miners will face in working in vacuum and without abundant water - surely not news to us! We have to pioneer not only whole new chemical extraction processes but engineer new ways of handling the raw materials involved. You have to grant him a sharp touché', however, when he asks how we can ever hope to do anything so difficult, when NASA can't seem to get even simple things straight these days.

Certainly no one should underestimate the engineering and chemical processing difficulties ahead of us. Unfortunately, most space advocates betray in their but-to-the-sofa fixed positions just such a naive grasp of the situation. We have a fearsome amount of homework to do. NASA is not doing it, and NSS seems to assume it will just all fall into place somehow. SSI by itself can only scratch the surface with the member-derived funds it has to work with.

Perhaps it is this all too nonchalant cocky conviction that we display in our bold scenarios for the future that encourages this open scorn. Our dreams of the future may turn out to be on target, but if we continue to rely on nothing more than let-George-do-it [i.e. the government] "activism", how will we ever know?

Herkenhoff lists an impressive bibliography. It is mute testimony that he has done his homework with prior bias in search of ammunition.

[Nb. Thanks to R. McNeil of the Willey Ley Space Society, the Chattanooga, Tennessee NSS chapter, for bringing this article to MMM's attention!] **< MMM >**

[Star*bound Series Cont.]

OORTFOAM

by Peter Kokh

Consider for a moment how a fire-devastated virgin forest slowly rises up from its ashes; only few plant species colonize the wasted area at first, then as they grow, niches are created that can be exploited by other plants. It can be a century or more before the original bio-diversity of the forest is restored. If the visiting devastation is very widespread, some areas may stabilize with a quite different mix of species than before. This is just a hint of what must have happened after a number of episodes of near global slate-wiping caused by large asteroid or comet impacts. When whole species, and sometimes whole families, of plants and wildlife are wiped out, hierarchical rebuilding of the niche-plexes of various eco-systems must chart fresh paths. Surviving plants and animals, previously held in check by now exterminated dominant species, are suddenly freed to exploit new opportunities and effectively 'encouraged' to evolve to do so.

The actual course of evolution has apparently been critically dependent on adventitious intervention of heedless celestial impactors. This periodic burst of freedom from the bonds of its own internal logic may be the only way it can be freed of its own ruts, even as the seed of some pine species can be freed of the host cone only through intense heat in an eventual forest fire.

Asteroids these days take much of the blame, or credit as I see it, for these clutch-hitting escapes from could-be evolutionary dead-ends. But comets, despite their lower densities, can arrive with far greater momentum if coming from well beyond the Asteroid Belt, indeed from well beyond the outer Solar System.

There are short- and long-period comets, tame (or tamed?) inhabitants of the realm of known planets. They revisit the coma-inducing warmth of the inner Solar System on a regular basis. Then there are those rare visitors throwing out hoary tails along one-night-stand hyperbolic trajectories from out among the stars, with too much speed to keep them from returning thence.

In between there comes the infrequent visitor on a scarcely parabolic path which will bring it back Sunward some thousands of years hence. If we assume that such gelid objects could not have formed in such eccentric paths, but must have coalesced in some more rational more circular zone of proto-star cloud material, where might that conjectured birthplace be? The answer according to Dutch astronomer Jan Oort, writing in 1950, was a vast spherical shell of pristine comet hulks thousands of times more distant from the Sun than Neptune or Pluto. Known as the Oort Cloud ever since, this region has been commonly imagined to drip Sunward great swarms of virgin comets whenever some passing star made an incursion into the neighborhood, clumsily disturbing their orbits in wholesale fashion. Balderdash!

One of the central assumptions behind all modern attempts at a scientific cosmology (or better, cosmogony: theory of the origin of the Universe as we now observe it to be) is the idea that what holds true anywhere, must, all else being equal, hold everywhere. Astonishingly, as religiously dedicated as most astronomers are to this principle, their seemingly unquestioning mass-attachment to the idea of Oort Cloud disturbances as the font of episodic cometary invasions of near-Sun-space gives it the lie.

SQUELCH ONE:

That comets with slow but enormous momentum in orbits tangential to the Sun, should somehow lose ALL of that momentum, and no less, to fall straight inwards, should happen about as often as every other lifetime of the universe. In other words, it ain't too likely.

SQUELCH TWO:

What's good for the Sun should be good for any other system-laden star. To think, even by default, that we are alone in having an Oort Cloud (if we do indeed have one, but that is not my dispute) borders on being discrediting. If, like two ships passing in the night, the Sun and another Oort-sporting star pass are another relatively hard-by (this should happen every few hundred thousand years or so) then it is far more likley that the Sun and its planets pass *through* the Oort Cloud shell of the *other* star, than that that star create precisely the kind of gravitational wake which will send ANY of our own Oort Cloud's inhabitants dead-on Sunward. Whatever comets may have restarted the stalled elan of evolution on occasion, have had at us from their orbits around *other* suns.

We are a long way from some General Theory of planetogenesis and solar system formation that will cover all the wide range of star and system types so as to allow us to say much more about "comparative oortology", if you will. But thing is clear. Oort clouds are, according to the original theory which it is not my purpose to question, too far out from their host suns, in comparison to average inter-star distances, not to loose members steadily by being routinely disturbed into some wide-ranging brownian dance. The number of rogue comets no longer belonging to the gravitationally shepherded flock of any star, must be rising steadily since the onset of star formation in the galaxy.

Nearer home, all our probes bound for Jupiter and the outer planets (both Pioneers and both Vikings) have passed through the Asteroid Belt ('thick' only in the imagination of artists and writers of space opera) as if it wasn't there. Even the thickest parts of the nearer Kuiper and remoter Oort comet clouds are considerably less densely populated yet - than the Belt. However, the 'urgency' of population density (if one can speak so) is *effectively relative to speed*. Our proxies passed through the much thicker asteroil belt at a relatively slow 10 klicks a second.

A people-entrusted interstellar craft slicing through our galaxy-wide "Oort Foam" at perhaps a mere 10% of the speed of light i.e. 30,000 times swifter, would effectively densify comet spacing by that same factor. The odds against an actual (anihilating) collision (the force of the impact increasing with the *square* of relative velocity) are still favorable perhaps, but only statistically. An ample-time warning system seems a long shot. Travelling at near light speeds may cut down on exposure time to cosmic rays, the amount of non-recyclable consumables needed for the trek (energy-generating needs) and other dangers, but it'll surely demand its own special courage. **< MMM >**

WOULD-BE STARFARERS QUIZ #2

by Peter Kokh

1. **Q**. How far from the Solar System would you have to travel before the star patterns of the familiar constellations became unrecognizable?
2. **Q**. Are all stars approximately the same age?
3. **Q**. Does the color of a star tell us anything?
4. **Q**. The Sun has 'sunspots' which come and go in pairs of eleven year cycles. Is this typical?
5. **Q**. Do stars ever collide with one another?
6. **Q**. Can the death of a nearby star effect the Sun itself, or life within our Solar System?
7. **Q**. Has the Sun always had the same neighbors?

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1. **A.** Bright nearby stars like Sirius, Procyon, Altair, Vega, Fomalhaut, Capella, and Arcturus would shift from their familiar positions by the time you reached ten or more light years from the Solar System in almost any direction. You'd have to travel a bit further before the stars in the Big Dipper started to shift noticeably, but Orion would hold its shape stubbornly until you were some hundreds of light years away. It may seem natural, and even romantic, to include the names of host constellations in the names of stars themselves (Alpha Centauri, Tau

Ceti) but what constellations they "lie in" is entirely a matter of local perspective, so that these names betray a very provincial chauvinism. Such names would not wear well - if and when civilization reaches an interstellar level.

2. A. No. Star formation probably began shortly after the matter contained in our condensing proto-galaxy reached a certain trigger density, maybe 14 B years ago. Almost all of the smaller, less massive, cooler burning K- and M-type stars formed at this time are still around. The more massive, brighter, hotter burning ones, long since consumed all their nuclear fuel and came to the end of their "mainstream" lives to end up as degenerate dense white dwarf stars, as even denser neutron stars (pulsars), or even as black holes. The Sun is about 4.6 billion years old, the age of the Solar System in general. Most of the bright stars you see have to be much younger since they belong to the short-lived variety. Some, like Sirius and Procyon, have companion stars that have already burned themselves out. There are indications this may have happened to Sirius B within historical times.

3. A. The color is a direct clue to the surface temperature of a star, and an indirect clue to the rate and intensity with which it is consuming its nuclear fuel (hydrogen burns into helium, helium into carbon, etc.) Red stars are coolest, orange ones a bit warmer. Then come the solar-type yellows, yellow-whites like Procyon, and whites like Vega. Bluish stars like Rigel, burn hottest and brightest. Dwarf reds live the longest, the blues occupying the limelight just briefly. When we study the spectrum of a star, its light passing through a prism to reveal the various color components, we see tell-tale black absorption lines which indicate the presence of certain elements. In general, stars that have lots of 'metals' (here meaning anything heavier than helium) are younger, having formed at a period when star-forming clouds in our galaxy had become more peppered with heavier elements fused in the cores and supernova explosions of stars already dead. Thus solar-type stars poorer in 'metals' than the Sun, e.g. Tau Ceti, must be somewhat older, say six billion years or so.

4. A. Sunspots are slightly cooler regions on the surface (they are dark only in comparison!) associated with magnetic storms. Solar flares share the same timetable. We know stars have flares, paradoxically, the smaller and cooler the star, the brighter and mote violent these flares can be. Some dim red dwarfs brighten considerably during flares. On hotter, brighter stars, flares are almost unnoticeable. We have found gigantic sunspots on the bloated surface of Betelgeuse, a star nearing its death.

5. A. Compared to the immensity of space, the volumes occupied by even the largest stars are like mere points. Galaxies, in contrast, occuppy much larger volumes of the space they cluster in, and sometimes do collide. We can see some galaxies in the process of collision. But while such slow-motion events surely have an enormous effect on the dust and gas clouds within the two galaxies, their individual stars must collectively pass clean through each other's interstellar spaces with no more than near misses. On the other hand, close binary stars can gradually orbit one another in ever tightening circles. Contact binaries have been observed. And quite often, in the pre-death bloating stage, one of the pair will expand to swallow the other. For hermit stars like our Sun, there is no danger.

6. A. It was probably a shock-wave from a bright nearby star dying in a supernova explosion that triggered the collapse of the dusty gas cloud from which the Sun and its planets formed. Some of the elements in our Solar System are present in atypical abundances for which this seens to be the best explanation. In general, all the atoms heavier than hydrogen within our bodies are star-ash from ancient stars long gone. But while the death throes of a nearby star like Sirius could certainly be a major happening in our skies (that there are no records of such a spectacle when Sirius B went Nova, may indicate it was behind the Sun in line of sight at the time), we are not 'currently' close enough to a potential supernova candidate to have to worry. But it won't be too healthy for those only a few light years from Rigel when its time cones!

7. A. Each star has its own orbit around the center of the galaxy, its own diverging trajectory, its own pace. It takes the Sun an estisated 250 million years to make one circuit. So our Solar System is only about 9 galactic years old. It is highly unlikely that the Sun is still any where near any of the stars populating the neighborhood of its birthplace. Nor, given chaos theory, could we ever reconstruct what stars were nearby at the time. You see, interstellar travel - by the stars themselves - has been around a long, long time. And we're aboard now!

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CLOACAL VS. TRITREME PLUMBING

by Peter Kokh

The Best Plumbing System for Lunar and Space Settlement Biospheres?

cloaca: (clo AH ka) = a common cavity into which the intestinal, urinary, and reproductive canals open in birds, reptiles, amphibians, and monotremes (the lowest order of mammals).

monotreme: (mo NO treem) = either of the two remaining species (duck bill platypus and spiny anteater) of the lowest, most primitive order of mammals, with one hole for all discharges.

SCENE: the lower Indus Valley about 200 miles NNE of modern Karachi, in the north part of Sind province, in what today we know as Pakistan.

TIME: some 4,000-4,500 years ago.

PLAYERS: a people, long since vanished from the area, but with increasing evidence that they were the ancestors of the populous dark-skinned peoples of today's southern India: the Dravidian speakers of Tamil, Telugu, Kanarese, Malayalam.

ACT I: fade from the ruins we see today, and known to us as Mohenjo Daro, back in time to one of mankind's first experiments in urban settlement - we do not know by what name its inhabitants called it - where the city fathers meet to accept the plans of their chief urban architect for the world's first urban sewer/drainage system: a network of gravity-gradient open ditches, into which all liquid-born wastes would flow off to same final place of out-of-sight/out-of-nind.

ACT II: there never has been an ACT II. Ever since Mohenjo-Daro, except for putting the sewer and drainage system underground and treating the effluent so that it commits less aggressive harm against neighboring communities, we have been in the rut of the very primitive duck bill platypus, stuck using a cloacal system to handle the quite different wastes from toilet (septage), bath and laundry (gray water), kitchen, and industry.

Lessons for the “New Towns” of Space

Except in "new towns", it would be prohibitively expensive to switch to a new 'multi-treme' system which keeps different types of sewerage separate from the beginning in order to benefit from simpler and more efficient source-appropriate forms of treatment, with the fringe benefit of enjoying whatever valuable byproducts such separate treatment may promise. Lunar and space settlements *are* "new towns". Infrastructure is 'change-resistant'. Therefore it is of *supreme importance* to choose it wisely from day one.

While in many other areas NASA has chosen to pioneer radically new technologies, the agency, and those involved in the 1977 Space Settlement Systems Summer Study, turned instead to existing urban models when it came to the basic architecture of plumbing and sewerage treatment systems. If you think of the opportunities for Earth-side spin-offs, this tack emerges as a major slip-up.

Let's explore the benefits of an alternative triple conduit or tri-treme drainage and routing system for future off-planet mini-biospheres.

1) Farm, garden, and lawn run-off, food-processing waste and kitchen garbage-disposal waste (if not saved to compost for home gardens): the water laden with them should be kept separate by a distinctively labeled and color and/or designcoded drain and conduit system. After sieving out larger chunks for composting, such water can empty into fish tanks without further treatment.

2) Gray water from showers, hand- and dish-washing, and laundry would similarly have a privileged routing system, to a treatment facility which would remove whatever biodegradable soaps and detergents are allowed, for composting separately. The remaining liquid could be run during dayspan through shallow near-surface ponds, top-paned with quartz, where 'raw' solar ultraviolet would sterilize it, killing all pathogens and bacteria. Simply cleansed and purified with the biodegraded cleaning agents added back in, this nutrient-rich water could go directly to farming areas and into the drip-irrigation system.

3) Septage (= urine and feces) can be handled next in several ways. The familiar very water-intensive water-closet flush toilet system could be preserved, connected to its own drainage net. Solids could be removed to be channeled through an anaerobic digester for composting and methane production [see "Methane" below], and suspended particles in the waste water treated by microbes to produce milorganite-type organic fertilizer. The clarified effluent would then go to the farm watering system. Or, the urine and fecal water might alone use a third drain line system, while fecal solids are 'collected' for separate treatment. [See "Composting Toilets" below].

4) Industrial effluent must be purified and reused in a totally closed on site loop with a high price for any loss make-up water piped in. Allowing industries to discharge water, of any quality, into the public drains system, invites than to pass on clean-up costs to the public. If all industries must play by this same rule, and cost out their products accordingly, there will be no problem with this make-or-break provision.

The 1977 NASA study recommended the use of a wet-oxidation (euphemism = incineration) process for treatment of all water-carried wastes indiscriminately. While this method almost certainly offers the swiftest turn-around for our costly original investment of exotic (= Earth-sourced) hydrogen, carbon, nitrogen, and possibly added phosphorus and potassium, on the order of 1-1.5 hours, it misses valuable and elegant opportunities to produce 'organic' fertilizers and other regolith-soil amendments which are far superior to chemicals in their buffered slow-release of nutrients and in soil-conditioning character.

In smaller space and/or lunar outposts, heavy reliance on chemical assistance for fast-cycling sewage treatment may be the only feasible way to go. But as we design settlements for hundreds or more pioneers, we have the opportunity, if not the duty, to consider more natural alternatives. Every part of our proposed tritreme drainage and sewage treatment system, has separately received abundant proof of concept on Earth. **< MMM >**

COMPOSTING TOILETS

COMPOSTING TOILETS

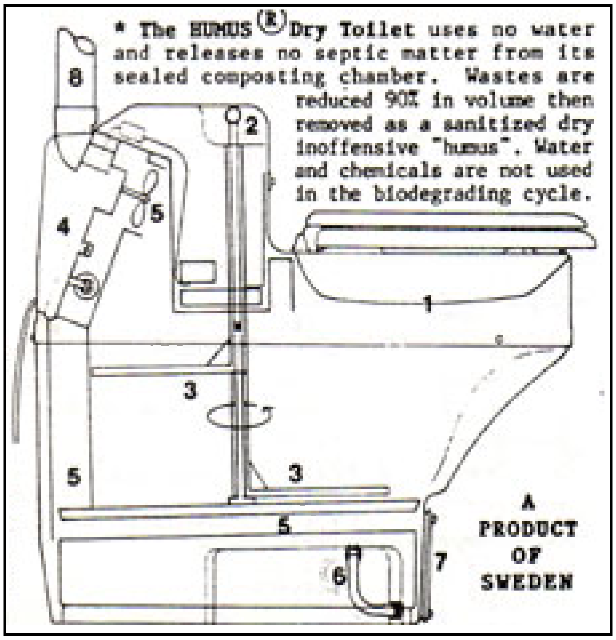
Advantages for the Lunar Frontier

by Peter Kokh and Doug Armstrong

With Thomas Crapper's invention of the water-closet flush toilet that immortalized his name, large segments of the world's population became freed of unpleasant odors from out-houses and/or the problems of having nowhere to empty pots of 'night-soil' save out-the-window or in a gutter. But convenient water-closets, whether attached to urban sewers or country septic tanks, are not the only alternative for sanitary disposition of one less pleasant side-effect of having a body.

On the market today are alternatives targeted primarily at owners and builders of remote homes and country cottages where the type of terrain may make septic tank installation impossible, and/or where it seems prohibitive or simply not desirable to tap a 'flush-away' water source. These wizardly contrivances are known as composting toilets. Using on-the-spot microbial biodegradation, they turn human wastes into good garden-ready compost without subjecting its user to unpleasant odors and with little expense.

Are such devices space-ready? Not quite. They require venting to an outside air-sink, a luxury we won't have in mini space or lunar biospheres. For our purposes, it will be necessary *either* to filter the "waste air" for direct inside venting *or* to devise a *waste air drainage network*, with all fetid and stale air channeled into fish tank aeration systems within farming areas. This can be made easier by not overloading the system to begin with. For example, the simple "conpostlet" or "COMPO" pictured below evaporates the urine. But the urine and fecal water could be collected in closed containers for separate treatment.



(1) Swingaway Chamber Cover - when lid is lifted, only clamshell disk shows. Pressure on seat makes halves swing open.

(2) Flush Button

(3) Automatic Aerators: Electric motor connected to flush button drives agitators, turning composting matter for full drying.

(4) Thermostat

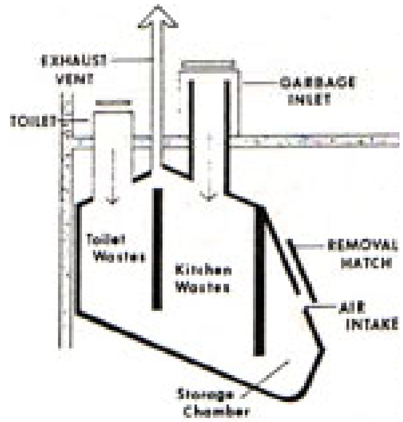
(5) Air Channels: fan drives warm air and oxygen through channels under compost.

(6) Level Tube: Fluid high level mark indicates need to reset thermostat. This function is readily automatable.

(7) Removable Tray Cover: The final dried compost lies in tray ready for emptying.

(8) Ventilation Pipe: For moist (urine) air and odors. If urine was drained into a sub-tray with odor trap, the venting need should be reduced to drying fecal matter.

This fetid air may be exhausted (a) indoors, through activated charcoal filter, or (b) via a common stale air duct-tree to be used to aerate fish ponds.



The HUMUS™ Dry Toilet is meant for occasional use by a few people. Much more capacious systems, like the Clivus Multrum type depicted here, will serve larger families on a full-time basis, and also handle compostable kitchen wastes from food preparation. Integrated systems such as this one might also find application in "space frontier" settings large or small.

Not only would compostlets put less strain on any settlement and outpost waste water treatment systems, their product, sanitary organic garden-ready compost, can only be replaced by chemicals expensively 'upported' from Earth only to do the job (waste treatment *And* fertilizing) less well. However fondly attached we are to flush toilets, however much we are inclined to scorn any alternative as an unwelcome throwback to cruder times happily behind us, the space frontier version of the compostlet is in our own best self-interest.

For those living in small off-planet quarters with no home garden space, and those who simply do not want to keep up a home garden in 'sunlit' space provided, a utility service could pick up sealed compostlet trays on a regular basis, to feed a communal composting operation. *Or*, luxury water-closets could be provided, flushing into a separate septage-only drainage system as suggested in the previous article. An appropriately steep installation charge and user fee schedule for this "carefree" expensive option could be charged to the accounts of those who insisted upon it.

Okay perhaps for large enough space frontier settlements with major farm operations! But what about the smaller outposts which will almost certainly be used as beachheads initially, both for lack of money and our need to build up know-how, experience, and confidence step by step?

In the long run, it'll pay us handsomely to treat human wastes as a "precious commodity" - yes, like gold or platinum - from the outset. *If* at first we cannot afford to bring along the means to compost wastes properly, *or* have no use for such compost, we can simply freeze-dry or otherwise immobilize the stuff *until* we *do* begin farm operations.

Incineration ("wet-oxidation") would be a grave misuse of a valuable free resource. A damn-the-future, let's-go-with-convenience attitude is not the way to bootstrap our way to any more significant realization of our space-faring ambitions. To say the least, the expediencies so lightly recommended by some planners, would be judged harshly by those trying to build on such beginnings.

In planning the next stage, *we must always peer ahead a few steps,* lest we venture off down any dark dead-end alleys. *Bad infrastructure decisions quickly become "entrenched" and change-resistant.*

Plumbing-As-Usual would be a costly case in point.

Think "Compostlets!" **< MMM >**

METHANE

METHANE

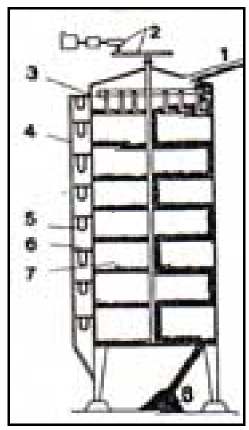
by Peter Kokh

Methane is the simplest, most common gaseous hydrocarbon. Incorporating one atom of Carbon and four of Hydrogen in each molecule, it is also known as "fire damp" and "marsh gas" It is the major component, usually more than 80%, of the "natural gas" widely used for home heating, industrial ovens and electrical power generation plants. It is produced naturally in human and animal food digestion, and emitted as flatulence (cows and termites being notoriously efficient at its production) *and* anaerobic (oxygen-starved) plant decomposition, such as at the bottom of a swamp or bog.

Without warning additives, it is clear and odorless, about as dense as air, and poorly soluble in water. Methane is combustible in air if certain threshold concentrations are reached, and slowly oxidized at any level. Over the long run, Methane can 'co-exist' with atmospheric Oxygen only if the former is continuously re-generated by the processes mentioned above. Thus seemingly stable co-existence of Methane and Oxygen in a planet's atmosphere is an almost certain indication of the presence of "life".

On the space frontier, we are unlikely to find natural sources of methane this side of the giant planets. Yet within the carefully tended mini-biospheres we must install in alien climes to re-encradle ourselves, methane has a roll to play - within limits. It may be ill-advised to brine along ruminants such as cows or even goats (which are far more efficient in producing milk and cheese) unless we are certain we can handle (i.e. collect or trap) their steady outgassings.

Methane is also produced in *anaerobic digesters* composting farm biomass waste (= parts of plants not edible to humans or livestock, as well as produce of reject quality). They are an especially efficient and quick way of rendering compost as opposed to the best window designs. [below]



Vertical Digester

(1) Inlet
(2) Rotating mechanism
(3) Plowshares
(4) Air pipe
(5) Manometer
(6) Orifice plate
(7) Deck &
(8) Compost

The Question:

So is natural Methane production within space and lunar biospheres something we should hold to a minimum = no cows or goats; incineration of biomass wastes, rather than the slower process of anaerobic digestion? Or does it offer us something of great potential to foster with care? Let's back up a bit.

At present we can only speculate when the day will come that will find us 'mining' lunar top-regolith for Helium-3 to feed yet unengineerable fusion power plants, and in the process extracting significant amounts of Hydrogen, Carbon and Nitrogen from the moondust as by-products. Until such a time, we will have to "out-source" these necessary ingredients for life. That will mean tanking them in either up-well from Earth, or at a potential 2/3rds saving in fuel costs, from a processing plant on Phobos or Deimos, strategic moonlets of Mars.

For ease of handling, it will be considerably more convenient and efficient to ship this vital threesome combined as liquid CH_4 Methane or liquid NH_3 Ammonia, than as separate gasses (though liquid N_2 Nitrogen is easy enough to handle if we need more of it than the amount co-importable with whatever Hydrogen we need).

In other words, we will already have on hand equipment to break up Methane and put it to good use in the process of introducing its component Hydrogen and Carbon into the biosphere system. Fuel cells that burn Methane and Oxygen are one possibility. Now with that possibility in mind,

> Tanks of liquid Methane - or Methane pipe lines - might be the most efficient way to ship energy from the main settlement (or the Spaceport) to distant outposts else where on the Moon.

But it gets more exciting. Methane is comparatively clean-burning in air (79% N_2) so far as Hydrocarbon emissions and Carbon Monoxide are concerned - Nitrogen oxides are still a problem.

So if we burn it instead with pure Oxygen stored in a tank just like the Methane, this will give us a Nitrogen-free combustion environment, an engine that exhausts only water steam and Carbon Dioxide needed by vegetation. Nor will that mean too much CO_2. NASA's "wet oxidation" process would incinerate *all* wastes without composting, dumping *more* CO_2 yet into the biosphere and probably more heat as well from equipment run by less efficient electrical motors!

By taking the pains to produce compost, we are left with a fuel which can be used to run agricultural equipment - at no extra expense - dumping its C_2 rich exhaust into the farm areas right where it is needed. As far as this writer knows, there are no existing engines that burn Methane with tanked Oxygen. However, we will be developing them anyway for Mars applications, as it is *the* ideal fuel for that environment.

Such engines could run plowing, tilling, harvesting, processing and drying equipment etc. They could also be used to generate extra heat needed in nightspan. Why not be the first to develop such an engine in your garage? **< MMM >**

BROWN DWARFS

BROWN DWARFS

by Peter Kokh

Long before the term "BROWN DWARF" became the established currency for referring to substellar bodies without enough mass to contract gravitationally to the point where spontaneous nuclear ignition can begin and be sustained, I felt that there must be innumerably more of such denizens of the dark [calling them dud stars, substars and finally "infrars" since they could shine only in the infrared than the stars themselves.

The argument is quite simple: among the known types of stars, the cooler and fainter the star type, the more of them there are, in a geometric ratio. Now if indeed there are far more "BD"s than visible stars, distances between then must be somewhat less formidable than those that quarantine stars and their planets-in-tow from one another. Our closest stellar neighbors, the double star Alpha Centauri with its tag-along, Proxima, are some 4.3 light years away (= 270,000 A.U.). As remote as this seems, more than 3000 times the known diameter of our Solar System, we are fortunate to have a neighbor so close.

If you take a list of all known stars within 10 parsecs (32.58 light years) as a representative sample, the "statistical average" distance between any one star system (binaries etc, count as one) and its nearest neighbor is 6.3 light years. There are some stars even 'luckier', of course. It's just a matter of breaks. One pair is only 1.1 light years apart. Stars drift and in the past we've come even closer than that to sundry stars, like "ships passing in the night".

Back to our story. If for every visible star system, I argued, there were ten "rogue" brown dwarfs, unattached to full-fledged stars, then the average distance between closest neighbor systems of either type must be 6.3 Ly times the reciprocal of the cube root of 11 (10+1) = 2.83 light years. That sounds a little more friendly - but don't get excited. It's still an unattainable distance given current demonstrated technology. If for every visible star, there were a hundred of such dark rogues, then that intersub-stellar mean closest distance would be only 1.35 Ly. You have to remember that space is *cubic!*

A debate has been raging over whether the universe has "enough total mass" to be gravitationally closed or not. Will current expansion eventually stop, even as a ball thrown up into the air, to be replaced by some final epoch of infalling contraction, or will the expansion and 'thinning' go on forever? The total of visible stars and known gas and dust clouds in all the known galaxies adds up to only 10% of the mass needed to "close" the whole. Some propose that the conjectured swarm of unseen brown dwarfs may possibly account for most of the "missing" mass.

So now these illusive objects are no longer just an absorbing topic, as we idly daydream of alternate pathways into the universe at large. Searching for them has become a top priority!

Those searching argued that some brown dwarfs may retain enough heat from their original formation, the heat of con-traction, to be detectable by special infra-red-sensitive telescopes. Until recently, we could not conduct such searches.

The water vapor in our atmosphere effectively screens out the infrared part of the electromagnetic spectrum. But now, new instruments on very high peaks such as Mauna Kea on the island of Hawaii at 13,796 ft (4300 m) poke above most of this water vapor screen yet that is still not enough to provide the sensitivity needed. Nor do the brief flights aboard NASA's infrared-equipped Kuiper Airborne Observa-tory suffice. So when the IRAS (Infra-Red Astronomy Satellite) went up in January '83, the search for brown dwarfs became a top priority.

While IRAS did make a serendipitous discovery of previously unsuspected proto-planetary "dusty" disks around some nearby stars like Vega and Beta Pictoris, no unchallengeable evidence of brown dwarfs was detected. Many, even some of the inves-tigators themselves, have jumped to the conclusion that the assumptions on which we've been postulating their existence are wrong, that there aren't any such critters.

IRAS was capable of detecting only those rare dwarfs with a fairly high temperature, such as they would have if they were recently formed. It is the more plausible assumption that the overwhelming majority of such substars were formed in the earlier waves of galactic star forma-tion and have long since cooled to a point where they emit heat too feebly to be detected by our current state of the art instrumentation. Further, the investiga-tors FAIL to admit, they have been looking only for brown dwarfs that are companions of known visible stars, not for those harder to find hermit rogues in sunless reaches.

So these intra-stellar substellar curiosities may still lurk out there some-where. If so, these hermit brown dwarf systems, despite the somewhat less intimi-dating distances between them, won't become stepping stones to the stars. It would be absurd to waste the fuel and the time needed to decelerate for a "pit stop" in such a system.

But, it is possible many of then have dwarf planetary systems not unlike Jupiter's, close-in and cold!. *and*, ample solar energy is not the only hook on which to hand our pioneering hat.

Circling some of these lonely dwarfs may be numbers of "oceanids" or "europids" [see MMM JUL '90 #37 article "Oceanids"], Europa-like moons with ample water oceans kept liquid by tidally-induced heating under vacuum-packed ice crust seals. Some day we may learn how to farm such ocean-trove moons, starting with Europa herself.

Communities of settlers could orbit in space settlements or live in shielded and insulated stilt-supported structures out on the ice-crust. For energy they could tap into strong magnetic differen-tials surrounding the brown dwarf or rogue gas giant, in much the same manner as OTEC (Ocean Themal Electric Current) schemes. This is a technology we probably must develop if we are serious about attempting to bring Jupiter's big Galilean moons into the human domain.

In a way he did not foresee, Arthur C. Clarke, co-author of "2001" the Movie (Saturn's Iapetus, not Jupiter, hosted the stargate monolith in the book version), Jupiter could yet become our dawn break-through point to the stars! **< MMM >**