

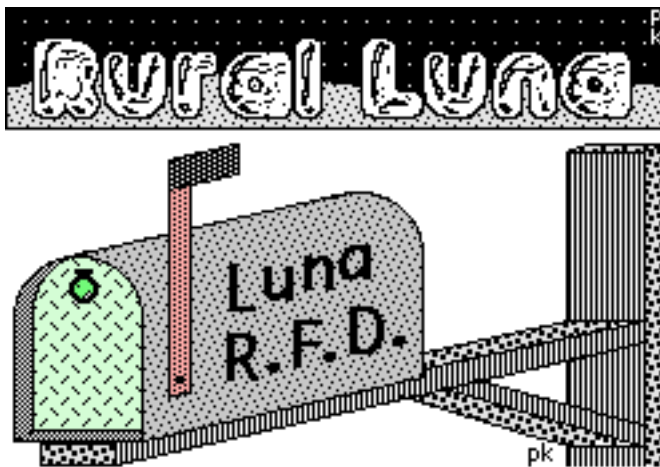
"Expanding the Human Economy through Off-Planet Resources"

MOON MINERS' MANIFESTO

MMM Classics
The First Ten Years

Year 9: MMM #s 81-90
December 1994 - November 1995

This year began with an extended revisit to one of our favorite topics, "rural Luna," the lunar surface at large beyond the main settlement(s). How would human presence extend ever further and further, slowly establishing a global presence for humanity?

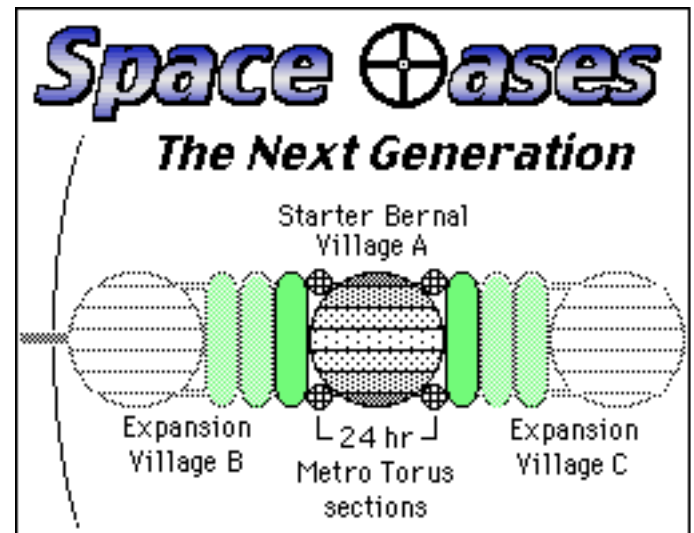


We had begun this "revisit" MMM #79, with a discussion of lunar roads, road signs, wayside service centers, and vehicle design constraints. Now we continue our look at the lunar "boondocks" in issues #s 81-86, covering such exotic-sounding topics as: Surface Vehicles & Transportation, Over the Road Long Distance Trucking Rigs, "Toadmobile" Conversions, "Skimmers" and "Spiders."

We looked at Camping Under the Stars, The Beaten and Unbeaten Path. Finally, we took up a look at what isolated rural homesteads or outposts or "Tarns" might be like and how they would be different from outposts designed to grow into settlements. We looked at various appropriate Tarn Architectures, Wayside Tarns, Farming Tarns, and Mining and Science Tarns. And, of course, our treatment would not be complete without a look at the inevitable false starts, the future Ghost Towns of the Moon.

In our annual Mars Theme issue, we extended these topics to look at "Rural Mars." Wherever mankind spreads, the mutual complementarity of rural and urban settings and life styles will follow. But on each world, in each new settling, there will be interesting new nuances and applications. And this duality will color the culture of each future human-adopted world.

Back in issues #s 11-13 [included in MMM Classics #2] we took our first comprehensive and constructively critical look at the topic of Space Oases, as we prefer to call them, originally dubbed Space Colonies, then redubbed Space Settlements in an effort at international political correctness.



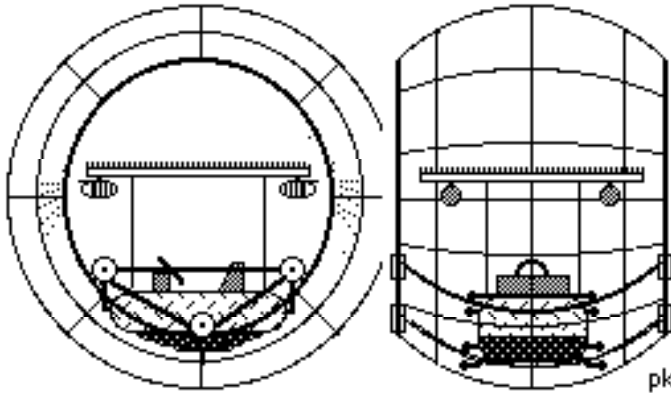
Now, seven years later, the Lunar Reclamation Society "think tank" playfully named The Copernicus Construction Company takes up the topic and takes the "constructive criticism" to the next level, challenging the original assumptions that Earth-normal gravity would be the norm, as well as the hidden "first shift chauvinism" of its academic authors and proponents. We suggested major revisions to the Islands I, II, and III architectures, as well as introduction of a whole new architecture to permit natural "biodynamic" growth. Our study took months, and was reported in MMM # 87.

**in the (new) beginning, ...
(Starting over on the Moon)**

In MMM #s 88-90, we began a new series of articles, touching on basics of a return to the Moon. "Bursting Apollo's Envelope" is followed by discussions on "Shelter" and "Site Management," Dust Control, Warehousing, and that scary boogeyman topic, "Overnighting on the Moon." *Enjoy!*

Lunar “surrey with the fringe on top”

Watched “American Gladiators” lately? Have you seen the “Atlasball” segment? Next time picture space suited lunar thrill-seekers working their geodesic cages along a rally course of craterlets etc. Might be fun if the sweat of exertion and the overheating inside one’s space suit could be handled!



Similar solar powered spheres could be equipped with a track riding buggy capable of generous side-to-side movement or banking. Such an “off-road vehicle” - call it a unicycle, an auto-tracker, a cyclotrack, or whatever - could open the vast lunar barrensapes to the sports-minded “outlooks” types and help avoid cabin fever. More on Lunar vehicles below.

[Series Continuation from MMM # 79, OCT ‘94]



Part II. Surface Vehicles & Transportation

Travel on the Moon, or Mars, won’t be as causal as on Earth for a long, long time to come. Nor will there ever be as many modes. On the Moon, air travel is not an option, and reliance on suborbital rocket powered hoppers would increase the strain on the quality of the vacuum, a unique industrial and scientific asset worth preserving at any cost and inconvenience. On Mars both of these options are open and viable. In this article, however, we are concerned with ground transport.

Getting from here to there over the lunar surface, or over the Martian surface for that matter, poses an interesting set of challenges. The most obvious of these, negotiating the trackless terrain, is the one that has received most attention. Innovative wheel/tire designs and terrain-hugging suspensions are what we have come to look for. In recent years with the exploration of the possibility of microrobotic rovers, walking contrivances and computer programs to operate them have been added to the repertoire.

A few years back, OMNI Magazine offered a \$500 prize for most innovative lunar rover design. Here too, the process of negotiating the terrain received the most attention. There have been some distracting bugaboos. For example, the

OMNI requirements included a provision that the vehicle be able to handle crevasses. Sorry folks, but apart from the ice caps on Mars, “there ain’t any”! At the same time, some very real, very salient challenges have received very little attention.

There is more to a vehicle than its interface with the ground! Other considerations need to be addressed:

✓ **the temperature range** over which the vehicle must operate: on the Moon, from 200 some degrees below to more than that above Zero Fahrenheit; on Mars, mostly in the colder part of this range. - Note that the Apollo rovers were operated only during the dayspan. This means special heat and cold-resistant lubricants must be formulated, perhaps that special bearings must be designed. It means that batteries and/or fuel cells must either be thermally well insulated or be designed to operate in extreme temperatures. Siliconized lubricants, super-conductive magnetic bearings, and thermally insulated power plants would all seem to be a part of the picture.

✓ **The distance range** over which the vehicle can operate without returning to base. Where time is not a consideration, a vehicle powered by solar arrays can operate continuously from shortly after sunrise to shortly before sunset some fourteen days later, then sleep through the two-week long nightspan. It’s range is not limited. But except for robotic exploratory and/or drone freight vehicles, time *is* a consideration. Speeds must approach those the terrain will bear. And nightspan travel may well be required.

Solar arrays may be used as auxiliaries but stored electrical power such as fuel cells may be primary. Another option is chemical power using “fuels” derived from the surroundings on route, for example powdered pure iron fines extracted from the soil, burned in oxygen. To our knowledge, no one has as yet been thoughtful enough or inventive enough to attempt developing the engine required. Once we have such an engine, a refueling depot infrastructure will be needed to allow indefinite ranging.

Certainly, like it or not, for free ranging capability uncoupled to refueling depots or caches, nuclear electric motive power is a prime option, that is, if suitably sized lightweight yet full-shielded units can be engineered. But that will be quite an engineering challenge.

Yet another range-expanding option is beamed power. BACKGROUND: For fleet vehicles operating in the immediate vicinity of a main base or settlement, power generated by *whatever means* can be beamed from a high tower to any non-occulted vehicle within a local range of several miles. [See the suggestion of Myles A. Mullikin in MMM # 31 DEC ‘89 “The Laser Power Tower” p. 5.] Such an arrangement could cover construction vehicles, delivery trucks, spaceport coaches, etc. The rooftop rectenna would be much lighter in weight than the alternative bank of fuel cells or batteries. While the beam could be adequately safeguarded by fail-safe feedback loops, the capacity of the power tower to feed a growing fleet of vehicles at different vectors all at the same time, is unknown.

Such a setup could terrace the way to the introduction of global beamed power from solar power satellite relays. This would allow unlimited free ranging. The problem here is that solar power satellites would have to be stationed in L4 or L5, the closest stable Moon-synchronous positions, some ten times

further from the lunar surface than similar satellites in geosynchronous orbit are from Earth. Given the fall-off of power with the square of the distance, that's a hundredfold handicap to overcome. SPSs in L1 or L2 only twice as far out as Earth's geosynchronous orbit (only four times as handicapped) would require enormous resupplies of station-keeping fuel. And the problem of feeding many vehicles all at once with individual tight beams is the same.

It would seem then that there are just three really practical systems: (1) free-ranging larger nuclear powered craft; (2) vehicles burning powdered metal in oxygen limited to routes for which intermittent fuel resupply has been arranged; (3) fuel cell powered vehicles, also limited to serviced routes.

As has happened on Earth, there will be an evolving mix of vehicles of different types and those that work most efficiently and conveniently and inexpensively and reliably will become the standard. Again, as on Earth, there may be exceptions for local fleets where special support infrastructures might make sense, offering economies of opportunity.

√ **consumable reserves** also limit the effective range of crewed vehicles. Air and water must be recycled and regenerated on board, probably without bioregenerative support except in larger craft. As to food, reliance must be on compact rations unless caches or depots have been arranged along the route. This limitation applies to otherwise unfettered nuclear craft as well.

The upshot is that travel over trackless areas, far from serviced routes, will be as non-casual as in similar situations on Earth, e.g. early Antarctic expeditions. Could one possibly have expected otherwise? MMMM

OVER THE ROAD LONG DISTANCE TRUCKING AND



More than the cowboy, few occupations have been so romanticized as that of the over-the-road long-distance trucker. It is a calling definitely not for everyone, keeping one away from home and family for long periods of time. Of course, one end run around this drawback is the husband and wife trucking team which provides not only conjugal company but relief behind the wheel, even around-the-clock driving.

There is a romance about the road. It differs, of course, depending upon whether one plies a fixed route over and over on a week-in week-out schedule or ranges all over the map picking up cargoes of opportunity. In the one case the litany of truck stops and other diversions becomes routine, in the other it always keeps changing, though its poetry is the same. Inevitably one gets to know many others in the trade and it truly becomes a way of life - in the blood, as they say.

Truckers drive by day. They drive by headlight. They drive by radio, and by CB, and now cellular. They reckon by rote, by map, and now by Global Positioning Satellite systems. They acquire their handles, name their rigs, and their lore is mythologized in many a melancholy tune.

Many a business is at their service: motels, garages, restaurants, and complete truck stops; hookers on CB, radio stations, tractor customizing shops, custom apparel makers. Many a time myself on the highway day or night between country cottage and city four hours apart, I'd spot the Moon in the sky and wonder: "will it be the same up there?" Surely, not at first. But then the driving influences, the incentives, the needs - they'll be there unchanged. At first it will be lonely out vac, carrying a load the interminably long empty miles from Port Heinlein to Clarke City through grayscape after grayscape against black star-rich skies, and even lonelier by nightspan. But inevitably, eventually, it'll be "on the road again."

Distinctive features of Lunar Rigs

The Cab has to be/to do a lot of things. It must be pressurized, thermally well insulated, and provide for routine activities: sleeping, eating, hygiene, first aid, entertainment, communications, and more. Obviously we'll need more than a pair of seats and a bunk. In contrast to the current luxury super cabs of many modern long haul truck rigs, the cab of the lunar rig will have to be a camper-sized cocoon, a traveling truck stop, to use an oxymoron. It will be "self-contained", have walk around space, a galley area, a lounge area, maybe even a spare berth or two so that the rig operators can offer "tramp steamer" type accommodations to occasional passengers.

As to the **cargo bed**, this can be either pressurized or unpressurized, depending on the cargo (cf. the distinction between refrigerated and non-refrigerated trucks). If pressurized, it is likely to be separately so. The twists, turns, torsional stress and vibration that comes with movement over a surface that is not straight, flat, and level would tax any connection critically. There would be match-lock pressurized access to the hold only when the truck was parked, straight and level.

The cargo area may have an accessible solar flare storm cellar at the bottom so that any cargo carried could act as shielding. The cab-cocoon itself may have a storm cellar cubbyhole in the floor area, beneath water reserve tanks, fuel cells, and other heavy equipment.

Rig class ratings will tell the type of routes the rig is able to handle: unimproved but scouted routes, graded routes, routes with tended way stations or refueling stations, fully serviced routes with staffed service centers, etc. in declining order. This will work to prevent both operator and customer from undertaking foolish ventures.

Rigs will be largely **self-servicing**. They will be equipped to **self-unload**, with their own fork lift or crane. Cargo will be containerized as much as possible to allow easy, fast, low-risk, low-exposure loading and unloading. The rig would boast a strategically-stocked parts bin and tool crib.

Rigs will be designed and engineered for **easy self repair**. Pop-in/pop-out independently-suspended wheel/drive-motor modules might be the rule, each getting electric power from a central plant. Each rig might carry a spare module, with standardized replacements available at service centers. The rig would carry a piggyback open rover **dingy** for emergency travel and capable of transporting replacement parts like wheel/drive modules.

Communications: both audio (radio) and video

services will be possible either via L1 relay, or direct from Earth. A low orbit satellite network is not an easy answer. It would be prohibitively expensive to maintain because the perilune or low point of low lunar orbits decays too quickly towards inevitable surface impact. Entertainment and news casts especially packaged for lunar truckers, if originating in the main or other settlements via L1 relay, could conceivably be a favorite eavesdrop for their earthbound counterparts.

Trucking in “deep” Lunar Farside, the 60° orange slice over the horizon not only from Earth but from relays in L4 and L5 as well, will require special communications arrangements. Perhaps a **roadside cable** with intermittent very-short range transmitters would allow one-way or two-way radio exchange say every few miles or every 15 minutes or so along the route.

Autopilots may be as popular and common on the Moon as cruise control on Earth. For there will be much less traffic; the slightest road jam will be fare for prime time newscasts less obstacles. The contingencies will be more routine. Autopilots may even be necessary for safety. For the very infrequency of situations requiring unprogrammable on-the-spot reflexes or reactions, along with the monotony of the scenery, unbroken by human-made structures and artifacts could tend to be very soporific.

Once there are a number of real settlements, there will be carriers who make the rounds, plying the circuit to pick up unordered specialty consignment goods in each community to make available in all the others. These “**Gypsy Traders**” will have pressurized holds and back up to settlement match locks in the “market “ area. Arrivals will be well publicized. The holds may contain their own display space, or else goods to be merchandised may be prearranged on rollout display carts and cases. Items will run the gamut from arts and crafts furniture, furnishings, giftware, souvenirs, and apparel, to home-canned specialty food items not otherwise available.

Servicing smaller less self-sufficient outposts and stations will be **traveling clinics** equipped for routine surgical procedures and other treatments. An ophthalmologist/ optician will be along. But these clinics will not be limited to medical practice. On the staff will likely be troubleshooting experts on agriculture and gardening, on recycling systems, and on biosphere maintenance. A dietitian will help plan strategies to meet deficiencies and other problems in the local diet.

A social worker and psychologist will be in demand, for lunar frontier life will have its share of stresses as well as rewards. An educational specialist will consult with outpost tutors. A writer/journalist will gather material for a round-robin news feature magazine and may need a sketch artist/ photographer. A specialty barber/hair stylist may have plenty of customers for non-routine makeovers. Etc. [See MMM # 35 MAY '90 “Tea & Sugar” pp. 6-7 for discussion of a similar traveling clinic/general store making the rounds between asteroid outposts.]

There will be lots of interesting jobs and occupations on the space frontier. One of them, offering relief from cabin fever within the settlement will be overland truck driving. However, settlements may need to train a large surplus of qualified drivers. Because of the **occupational hazard** of

accumulative radiation exposure, overland outgates driving will be only a part time occupation. Each driver will wear a bracelet that indicates accumulated rad exposure. Hired drivers and independent rig-operators alike may be scheduled to drive only a few months each year, alternating with another line of work, an ideal regular shot-in-the-arm morale booster. Or they may be scheduled to make but one round trip each lunar month. Such a situation will spur the rise of **Coops** of Independent Operators and co-owned rigs. At any rate, there should be no shortage of candidates. MMM

[Designing “Amphibious” Spacecraft Cabins to be transformed into Lunar Surface Craft]

TOADMOBILE CONVERSIONS

by Peter Kokh

The problem is easily stated. Our first returning crews will need surface transport on the Moon immediately. Further, as the base expands and undertakes more activities, its surface transport requirements will grow and diversify rather quickly. Yet the day when such vehicles can be manufactured on site is far off. How do we get these craft to the lunar outpost site in the most economically sensible way?

Consider that a lunar surface craft is still a spacecraft. It has to have a vacuum-worthy pressurized hull, have thermal control, micrometeorite protection, full radio communications, power reserves, etc. etc. The lunar surface, after all, unlike that of our home planet, is an interface with vacuous space itself. It is not the pressurized cabin that differs, but the motive chassis. In the one case we need rocket thrust propulsion, in the other we need wheels or legs. At least the cabins can make the trip to the Moon carrying people.

One can enter this in the books in either of two ways: (a) the fares of Moonbound passengers pays the freight bill on the transport cabin; (b) the passengers ride free or at reduced cost, almost as stowaways, the bill being paid by the agent ordering the vehicle for lunar surface use.

Thus at least some Earth-Moon passenger cabins will in fact be built for “amphibious reassignment”. Those whose design is maximized for freight hauling, or for equipment-laden field trips with minimal crews, are likely to be reassigned upon completion of their first outbound trip. Those made as passenger ferries may serve in this capacity for a good number of round trips, and then “retired” to surface duty as a “coach” after being mated to new ground-chassis in a final overhaul just before its last trip out from Earth orbit.

How many trips would such a cabin make before being reassigned to the surface? This would vary as the average crew stay time lengthens and as the number of people coming out to the Moon each month grows in ratio to the number returning home. For example, instead of each ferry returning to Earth at 75% capacity, every fourth ferry landing could be a final one, with the cabin wheeling off into the lunar Sunset, while the other three returning home full. Or in other words each ferry would make three round trips, followed by a final one way trip, to drive happily ever after over the moonscapes.

Obviously, this process can either be allowed to just “happen” or it can demonstrate a great deal of forethought. For example, ferry craft can be designed to optimize their usefulness as lunar surface coaches, at least where doing so would not compromise their safe functioning as a ferry en route.

The same double service design principles can be applied to pressurized holds as well as to crew and ferry cabins. We will need such holds and ready-to-outfit hulls on the Moon as well as en route.

Other lunar surface needs will be rather specialized and make for less than ideal ferries. Yet they need not make the journey out empty. Perhaps cabin importer and passenger(s) can split the savings. Beside mining crew, road-building crew, intersettlement, and spaceport coaches, say in the 20-50 seat capacity range, we will need mixed passenger/freight vehicles and trucking rig cabins meant for one or two people, crane cabins, cabins on regolith moving equipment, etc.

But we will also need cabins that are towed to a site and semi-permanently parked as construction shacks, film-making headquarters, prospector camps, etc. Indeed, such sedentary usages may account for a large part of the demand.

Clearly, there is the need for a great deal of preplanning if surface needs are to be met in a “just-in-time” fashion. Space craft production without forethought to their eventual longer term aftercareers would be foolish, and work to hamper and drag down the growth of any outpost or settlement.

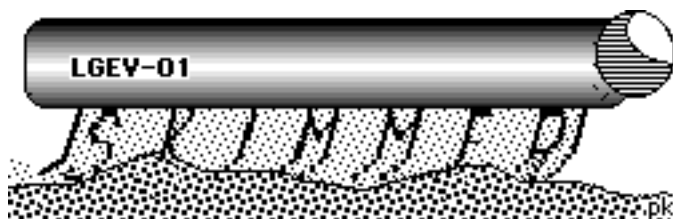
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Cf. MMM # 48, SEP '91 pp. 4-6. “Hostels: Visiting Vehicle” [included in MMM Classics #5] and online at: http://www.lunar-reclamation.org/papers/hostels_paper1.htm

BEYOND THE BEATEN PATH

Having to restrain the globalization of the human presence on the Moon and Mars to the pace of grading/building conventional road networks would put a real damper on the rate of growth of Lunar and Martian development and industrial diversification. Yes, conventional “off road” vehicles can be used. But they will be both slow-going and constrained to the more “negotiable” routes.

Below we examine some less conventional vehicles that could help quicken the pace of world building on the Moon, and Mars too.



by Peter Kokh

Given that there is no atmosphere of consequence on the Moon, and precious little on Mars, the idea of using “hovercraft” or Ground Effects Vehicles to traverse off-road

routes on either of those worlds is patently absurd. *Or is it?*

Yes, of course, we can’t just apply power to a downward ducted fan on a flexibly skirted vehicle and expect it to go anywhere. But it is not the ducted fan but skirt-contained overpressure that is the essence of hovercraft. On both worlds, both because the gravity is less and the prevailing atmospheric pressure is lower than on Earth, the amount of trapped pressure needed to produce adequate lift will be much reduced. And conceivably at least, there may be a couple of ways to effect just such weight-compensating overpressure. All that is lacking is inventiveness, simulation, and testing.

Skimmers could provide the key to the globalization of the human presence on the Moon; on Mars as well

The market for a practical system could be rewarding in both locations. Skimmers could navigate rugged trackless boulder-strewn terrain at *greater speed and comfort* than any wheeled or walking vehicle. If practical and economically feasible to engineer and manufacture, the timely introduction of such skimmers could provide the key to the globalization of the human presence on the Moon and Mars, greatly reducing the need to grade/build extensive road networks, and helping preserve the lunar terrain in a more natural, wild state.

Terrestrial applications sufficiently profitable to drive “spin-up” predevelopment of analogous fanless craft on Earth in the near future are possible but admittedly not obvious to the writer. We welcome your suggestions in this regard.

Chemical propulsion for lunar skimmers

On the airless Moon, gas pressure retained under a ground-hugging flexible skirt can be produced by any rocket type thruster. Obviously we do not want either to be importing fuels for such purpose or to be using a combination whose vital working exhaust remains volatile. The ideal solution is an engine burning powdered lunar-mined metal in lunar processed oxygen. The exhaust, having done its lifting work, will settle back to the ground as an iron or aluminum oxide powder. That may visibly mark the path taken but hardly contaminate it any sense of the word. Such engines are yet to be engineered, even though the chemical possibility has long been known. One big potential problem lies in the weight of the fuels to be carried and/or the need for an infrastructure to provide for convenient en route refueling. While the range of the fully fueled Fe/O or Al/O lunar skimmer will be limited, one must bear in mind that since only a sixth the lifting power required for a similar craft on Earth will be needed on the Moon, a full tank will go for a surprisingly long way.

Dust-Pressure Skimmer Systems

Very large lunar skimmer craft more like barges than trucks or busses might be able to handle the lunar gravity reduced weight of a small submarine type nuclear propulsion plant. The power generated could feed a laser rake or sweep just to the rear of the front skirt, the effect being to stir up a lifting cloud of regolith dust, possibly enhanced by released fine-adsorbed gasses when traveling over virgin terrain. Would the lifting power so generated be sufficient for the job, marginal, or totally inadequate. We don’t know. Back of the envelope guesstimates from readers are most welcome.

If such regolith dust-cloud pressure is just marginally adequate given the weight of the nuke plant necessary, one solution may be to substitute beamed power from a solar power relay satellite. Beam driven skimmers could be a long time coming, waiting upon a space power infrastructure.

Skimmers could serve as personal transport, as trucks for priority shipments to isolated outposts, as go-most-anywhere platforms for selenologists (lunar geologists) on field trips, and for prospectors. They could also serve as rescue craft and ambulances.

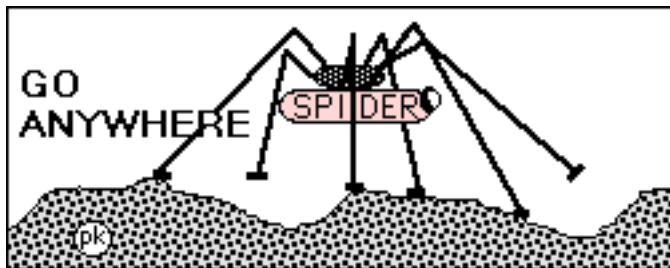
Skimmers will be limited in what they can carry, at least relative to their own mass, size, and hovering thrust. But that constraint applies to most any vehicle, even on Earth.

Very large skimmers with broad beams could serve as “mare cruise ships”, leaving “wakes” but no tracks on the long frozen lava seas of the Moon, leisurely making the rounds between ports of call. They could import wholesale much of the romance, lore, and mystique of Earth’s high seas. Why not?

Mars skimmers:

Different problem, different solution

On Mars, we do have an atmosphere, albeit a very tenuous one, and that offers us opportunities unavailable on the Moon. It means we can use hydrogen-filled bags for buoyancy, reducing the effective weight of the craft to be levitated off the terrain. It means we can compress the atmosphere itself to use as a lifting gas, though this will be harder to do than on Earth. It means the starring role of the skimmer on Mars is much less problematic than on the Moon.



by Peter Kokh

One model from nature of a creature that can go just about anywhere is the spider. I have in mind particularly the mobility architecture of the “Daddy Longlegs”, in some places known as the “Harvestman”. Might not a lunar (or Martian) traveling conveyance of similar articulation and ability become an indispensable asset in opening up the more difficult reaches of both frontier worlds?

The Spider’s “body” would consist of two separable components: the “trunk” would contain the “hips” for the six legs and associated “musculature”, and the power, fuel, and motive plants. Underslung by a “dead man’s winch” would be the crew cabin. This position gives it shielding protection from the locomotive complex above as well as an unobstructed view of the terrain below. If power should fail, the crew cabin would automatically winch to the surface in a controlled descent. This deployment could be overridden, if there was any reason to remain aloft.

The scale of such a contraption could be rather large, in fact the larger the better within practical limits. The legs could be long enough to elevate the central pod complex some dozens of meters above terrain obstacles below. This height would also be of great advantage in scouting a pathway ahead.

The spider gait could bionically mimic that of real spiders and include a cautious grope as well as a trot of sorts when the going permits. All it takes is a computer program.

The feet, the knees and hips as well, could be sensor laden, feeding back first to neighboring and partner legs, then to the central nerve center. In this respect the model might rather be the loosely decentralized manner of the octopus. [See MMM # 45 MAY ‘91 ROBO ANTS” pp. 2-5] [included in MMM Classics #5]

Difficult Terrain Exploration

In the saturation bombardment craterland of the lunar “highlands”, it is in general possible to make one’s way by sticking to “intercrater” plains, ridges, and shoulders, avoiding steep inclines. But what if we want to visit the central peak of a debris- and boulder-strewn crater such as Tycho?

On the maria, the darkish solidified lava sheet “seas”, the going is generally easier, craters of size being fewer and further in between. But even the flatish maria are laden with obstacles such as sinuous rilles (relics of large collapsed near-surface lavatubes), lava sheet flow front escarpments, “reefs” of incompletely buried pre-flood “ghost” craters, and of course the ramparts of “coastal” impact-upthrust mountain ranges. Such obstacles could make circuitous detours the norm rather than logical straight line routing - that is, if we are traveling by vehicle with limited ability to negotiate rough terrain.

On Mars there are similar relatively smooth and relatively rough areas, and similar obstacles. To be added in the mix are difficult landforms unknown on the Moon: crevasse-ridden layered polar ice caps, eroded slopes of the great shield volcanoes, dendritic tributary and distributary channels of ancient river and flood courses, chaotic labyrinths and canyonlands. Many of the geologically and/or mineralogically (thus economically) more interesting spots on Mars lie smack in the midst of such harder to reach places.

Cache Emplacement

A go-anywhere spider vehicle could do preliminary geochemical assessments along its route, and emplace seismic monitor stations. Where such dust and rock samplings warrant, it could then put in place handy base camp supply caches for follow-up field expeditions and prospecting efforts.

Construction Crane Workhorse, Webspinner

A heavy-duty version of such a straddle-everything pick-its-way-anywhere vehicle could serve as a crane. As such it could do yeoman work in relatively urban settlement sites as well as in remote construction locations, becoming in this version the workhorse of lunar development, as well as scout.

Specialized versions could spin arrays of cables across craters to make radio telescope dishes and space-solar-power rectennas. They could also spin cables across rilles from shoulder to shoulder for bridges or to support habitat meta-structure roofs. Indeed, it is hard to see how we could long manage without them.



[Shelterless travel]

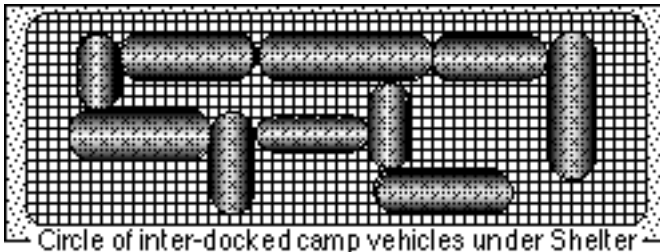


Roughing it for real!

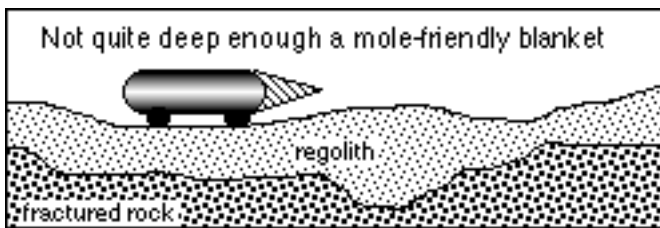
by Doug Armstrong and Peter Kokh, CCC

Off-road vehicles will not only ply trackless terrain but range far from convenient roadside flare sheds or wayplexes [see the articles on these topics in the October issue]. Short round trips can be ventured without provision for significant radiation shielding. But in times of Solar unrest especially, in Flare Season so to speak, off road vehicles must be prepared to “dig in” one way or the other.

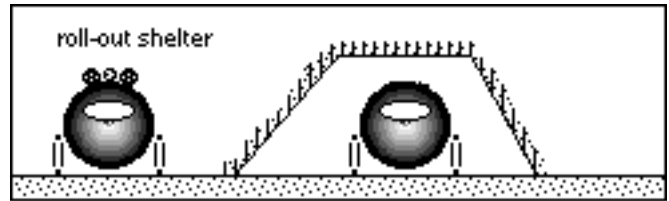
This need is critical for remote construction site camps as well, whether engaged in building new outposts, mining operations, or road work. For the latter some sort of semi-permanent storm shelter would seem to be an immediate priority of setting up camp. Camp vehicles would normally park in an inter-docking array under the shelter. But here we are concerned rather with the situation for vehicles en route.



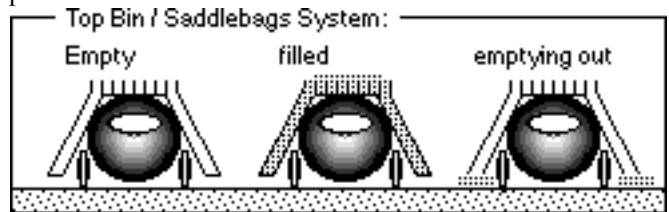
Copernicus Construction Company [CCC], the for-fun design and brainstorming activity group of LRS, has given some thought to how sudden shelter can be provided. One idea, coming straight out of a comic book read four or more decades ago, is to have a giant screw on one end of the vehicle so it can literally bore its way forward or backward into the powdery regolith. The problem here is that the regolith layer is in some places only a meter or two thick, not quite deep enough.



Another possibility is to carry along a collapsed, easily erectable space frame shelter and unrollable fiberglass canvas cover over which a scoop/conveyor system could blow regolith dust. Once deployed, such a shelter could be left in place permanently, its site marked on official maps for the convenience of others in the future. That leaves the vehicle, however, without protection if another storm should rise later at a point further along the route. Devising a way to “empty” the spaceframe/canvas shelter of its regolith overburden so that it can be packed up and stored on the vehicle rooftop or side for future use is an interesting engineering challenge.



Another system we thought of is an emptiable rooftop bin system with emptiable side mounted “saddlebags”. A scoop/ conveyor could fill the bins and bags as needed. The need past, the bins and bags could be mechanically opened and the dust would pour out as the vehicle moved out of its parking spot.



Actually, in latitudes some distance north or south of the lunar equator, the problem becomes easier. All that's needed is a sloping shed facing Sunwards (recall that the Sun creeps slowly across the lunar sky at only 1/28th the pace we are used to on Earth). A Solar Windbreak will be easier both to deploy and fill and to empty and return to rooftop standby storage.



Even small open rover type buggies, should they venture much beyond the point of easy swift return will have to be equipped with some “KD” (easy erect, easy “knockdown”) system of flare storm protection. All vehicles of any kind, when parking at a site along the route for a few days would be advised to deploy their shelter system as a matter of prudence. In the meantime, even under calm Sun “weather”, the voyagers will be at reduced accumulative exposure to the weaker but incessant cosmic rays coming from all sky vectors.

At the heart of the matter is the functional analogy between the protective high pressure atmosphere of Earth and the regolith blanket which can serve as a condensed solidified atmosphere for the same protective purposes. T.M.M.

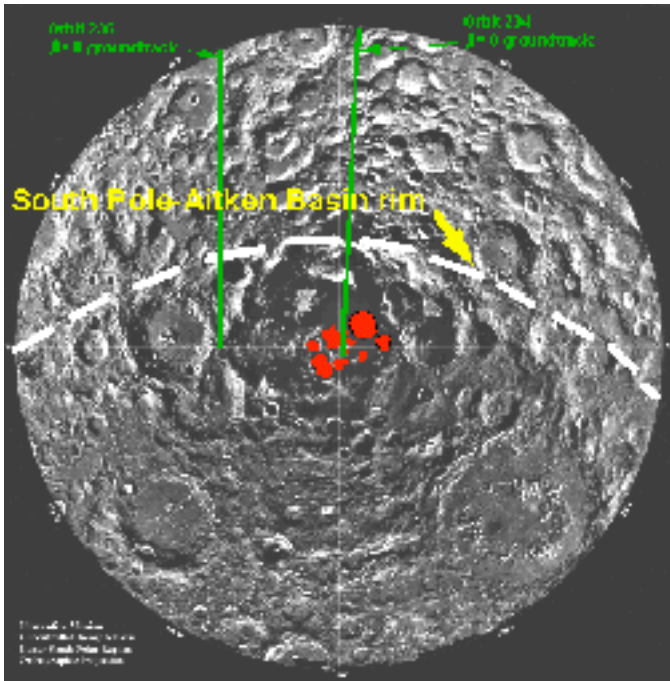
Relevant Readings from MMM back issues:

[Included in MMM Classics #1]
MMM # 5 MAY '87 “Weather”

[Included in MMM Classics #4]
MMM # 37 JUL '90 “Ramadas” p. 3;
“Flare Sheds” pp. 4-5.

[Included in MMM Classics #8]
MMM # 74 APR '94 “Shielding & Shelter” pp. 5-6.

Site of the principal *secondary* lunar outpost?



Above is a 1,500 image mosaic of the lunar south pole, courtesy of *Clementine*. It shows a 300 km-wide impact basin that never receives sunlight. The temperature in this permashade may be as low as minus 230° C (- 382° F), serving as a cold trap for water and other volatiles arriving on the Moon in nighttime comet impacts and migrating to the pole before sunrise when they'd be carried off into space by the solar wind. If such deposits are extensive enough to be of economic significance, and if harvesting equipment can manage the extreme cold, the water available here would be invaluable. Its primary initial use may be for rocket fuel. Long term, its use for agriculture and industry will be far more significant. As these uses will require other lunar materials better sourced elsewhere, any initial south polar base would soon play no more than a major supporting role. More below.

[Series Continues]



Part III: The Beaten Path: possible early development of multiple lunar sites

by Peter Kokh

If we find water ice at either pole, that just makes certain that we will need “more than one” lunar outpost site and we’ll need them *in the near term*.

One technician’s early read of then still incoming data from the Air Force/NASA *Clementine* orbital mapping probe, teasingly left open the possibility of fields of water ice (of unspecified expanse and depth) in a previously undetected deep

lava-free impact basin at the south lunar pole. The eternal frigid cold (-230°C, -382°F) of the permashade there would tend to cold trap any comet impact derived volatiles successfully migrating to the area before the incessant Solar Wind buffeting the dayside could sweep them into space. Such deposits would slowly build up over geological time only if the accumulation rate is great enough to swamp the several loss mechanisms that must work tirelessly to erode them. That’s a tall order, and we personally have expected a negative finding. All the same we have unwaveringly supported efforts to find out for sure. We cannot intelligently plan lunar development without knowing where we stand on the hydrogen problem.

Many others, however, optimistically anticipating a positive find of economically significant volumes of water-ice have declared that any such discover would settle the debate over outpost or settlement location. That’s a curious conclusion! Is Los Angeles next to Nevada’s Hoover Dam? Is Pittsburgh in Minnesota’s Messabi Iron Range?

Water, or more specifically the hydrogen of which it makes up just 11% of the mass, is undeniably quite essential to lunar development of any kind, of any extent. We can use it up obscenely and squanderingly for rocket fuel if we are too lazy to explore more lunar-appropriate options (silane, SiH₄, a hydrogen “extender”; powdered metals, etc.). But we certainly need it for food and fiber production and biosphere operation in general. Water and hydrogen both are hard to do without in “industry as we know it”; and finding cheap, accessible sources would make unnecessary taking up the difficult and unwelcome research challenge of finding anhydrous “xero-”processing and manufacturing methods.

Yet it is “not by water alone” that lunar pioneers shall live. If we are really going to use lunar resources, the tonnage of hydrogen and/or water needed in comparison to the tonnage of other elements will definitely be minor. For real industry, a “coastal” site at which both aluminum-rich highland and iron/titanium-rich mare [MAH ray] regolith soils are accessible would make the most sense. There are no mare areas near either pole!

Some of the other things we most want to do on the Moon ask for more equatorial sites as well: a deep farside radio astronomy facility; lunar solar power arrays on the E and W limbs. Obviously, if we find water ice at either pole, that just makes certain that we will need more than one lunar outpost site and we will need them *in the near term*.

Implications of South Polar Ice for “Rural Luna”

Our topic in this series is “Rural Luna”. What impact would a confirmed find of economically recoverable deposits of water ice at either pole have on rural lunar development away from the main base, or bases? That comes down to a question about transportation. How do we get resources from where they are found, to where they will be used, i.e. to where they are in most demand?

Suppose we set up an ice-mining outpost at/near the lunar south pole. And, option A, we have another settlement supporting He-3 recovery in one of the nearside maria [MAH ria]. Or, option B, we have two settlements one somewhere on each limb (between nearside and farside, from which Earth is on the lunar horizon) to manufacture components for, and

construct and operate vast lunar solar power arrays. Or, option C, we have a mining settlement along the nearside equator which sends lunar material via mass driver catapult into space for solar power satellite construction camps in the L4 and L5 lunar co-orbital fields. How do we get ice, water, or just hydrogen from the pole(s) to where its needed - at any/or all of the above?

We can do so by suborbital hopper, and make quick history of the lunar vacuum in the process. Or, much more interestingly, in a more environmentally friendly fashion, we can ship this polar elixir overland - by road and truck, and/or by pipeline. Routes leading from either pole to industrial sites elsewhere would engender "the beaten path".

Pipelines would need intermittent pumping stations and maintenance crews with intermittent shop/habitat facilities out of which to operate. Roads would need intermittent flare shelters and wayside sources of fuel, communication, and repair facilities. [Cf. "Waysides" and "Service Centers & Inns" MMM #79, Oct. '94, p. 15, republished in MMM Classics #8]. Some of these might in time evolve from visited, to tended, to permanently occupied settlements in their own right.

Since the first suggestion, ice/hydrogen transport by suborbital hoppers, is so unpregnant, so over and done with, let's assume common sense and the bottom line unite to beat overland paths between the pole and other sites. Does a look at the lunar globe tell us anything interesting?

A lot depends on where ice is found, at both poles, or only at the lower lying, colder south pole. As luck would have it, it is the north pole that is the handier to mare "coastal" sites. The north "shore" of Mare Frigoris (the "Sea of Cold"), lies within 27° or 500 miles of the North Pole. The southernmost "shore" of Mare Nubium (the "Sea of Clouds"), lies 60° or 1130 miles distant from the South Pole. From either of these coastal access points, the going gets easier to points anywhere in the connecting and clustering nearside maria.

The suspicion is that Helium-3 is more abundant in those mare areas that are ilmenite rich (ilmenite is an iron-titanium oxide ore). But such sites are to be found in many places. A South Pole only find would give the location advantage to helium-fertile sites in southern hemisphere maria like Humorum, Nubium, Nectaris, and Fecunditatis.

Another southern hemisphere mare, this one on the Deep Farside (over the radio horizon from L4 and L5 as well as from Earth), Mare Ingenii (the "Sea of Ingenuity") should be on the short list for siting an extensive Farside Advanced Radio Astronomy Facility (FARAF) [cf. MMM #10 Nov. 1987 "FARFAR" Part II, republished in MMM Classic #2.]. It may or may not be a good place to harvest Helium-3 as well. It would be more accessible to ice reserves at the South Pole than any other site on the short list (the flat mare-filled craters Tsiolkovsky and Aitken, and Mare Moscovense, for example).

A mass-driver feeding construction in space (e.g. L5) would most efficiently be sited on the equator, some say about 30° E in Mare Tranquilitatis (the "Sea of Tranquility"), not far from the Apollo 11 touchdown site as happenstance would have it. The path from the pole would probably be via Mare Nectaris (the "Sea of Nectar") and the Rheita Valley.

Dr. David Criswell, leading proponent of Lunar-based

solar power arrays, proposes siting them in Mare Orientalis (the "Eastern Sea") on the West Limb and in Mare Smythii, ("Smyth's Sea") on the East Limb. Now Mare Orientalis and associated Lakes (e.g. Lacus Verus) are the only choices in the West, and as luck has it, they are centered 20° S of the equator. Mare Smythii, on the other hand, is right on the equator and definitely not the only choice. Mare Australe (the "Southern Sea") is also on the East Limb but only a bit more than half as far away from the South Pole. If either we find no water ice anywhere, or we find it at both poles, Criswell can have Mare Smythii. But a "South Pole only" find would make Mare Australe clearly the prime choice.

If we go the route of Lunar Solar Power Arrays on the limbs, there is also likely to be an overland route between the two. Nearside routing offers easier terrain, the bulk of it through mare areas. The impact of a South Pole Only find would be principally on the easternmost quarter of the traverse: from Orientalis through Tranquility, the logical "easy" route (Orientalis-Procellarum-Imbrium-Serenitatis-Tranquilitatis) would not be affected. Giving the nod to Australe over Smythii, however, could lead to an early pioneering of a 'shortcut' through the southern nearside highlands (Orientalis-Humorum-Nubium-Nectaris-S. Fecunditatis-Australe). Along either of these paths-in-the-beating, tertiary rural outposts and someday settlements are sure to rise.

Land Grant Spheres and Corridors

Confirmation of significant water-ice fields at either pole would create a dynamic economic polarity of Sunlands and Permashade, heat and cold, fueling the lunar development engine. Along the field lines of this polarity, "rural Luna" would arise first, thereafter spreading further afield, "off" the beaten "hydro" track.

A lunar development authority ought to legislate two types of special Development Zones. (1) Settlements should legally include **hinterlands** of some radius (to be determined, we would suggest *at least* 200 km or 120 mi) within which they have reserved mining rights to outlying resources of importance to their economies.

(2) Road Construction Companies and/or Pipeline Companies might also get real estate concessions in the form of **corridors** of a width to be determined - much as was granted to some of the U.S. western railroads. They in turn, would have the right to sell or lease lands within those corridor limits to mineral lode and tourist site developers and homesteaders. This would work to accelerate the establishment of Lunan civilization along these pathways.

Homework: surveying prospective routes

Thanks to *Clementine* and the vast amount of orbital mapping data it produced, we can start now to narrow down the logical routes northward from the South Pole to Mare Orientalis, Mare Nubium, Mare Nectaris, Mare Australe, and Mare Ingenii. At least the preliminary work in each instance could be done by anyone with access to Clementine data. Perhaps here is a chance to get your name in the Lunar History books. Other routes (East to West, etc.) also need surveying. Optional route locations need to be rated in terms of construction difficulty and consequent expense. As on Earth, the easiest routes come first, engineering miracle shortcuts later.

Actual traffic routes are not always determined by the path of easiest construction, however. They can be distorted or attracted off the expected route by specific site-anchored assets. Especially promising ore deposits, if identified before hand, can influence the final choice of route. So might outstanding tourist attractions (e.g. The Straight Wall). While a number of non-topographical considerations may influence final corridor selection, a short list of promising routes can be put together with the information we already have.

**The Beaten Path
Nearside Routes**

[dark areas are
lava sheet-filled
mare basins]



**The Beaten Path
Farside Routes**

MMM

MMM #83 - MAR 1995

— searching for —
OLD LIFE
— on Mars —

Two different questions - two different searches

Conditions on Mars were relatively friendly to the rise of primitive life for perhaps a billion years. We could find fossil algae mats, even limestones produced by living organisms. It took 3+ billion years on Earth for metazoan (multi cellular) creatures to appear.

On Mars there is only a slim chance of finding anything so advanced as a fossil sponge. We might find some incomplete strands of DNA. Genetic reconstructions are unlikely.

Surviving life is another matter. Solar ultraviolet radiation leaves only the interiors and undersides of rocks as likely habitats - only where midsummer thaws occur *below*.

The Proposed Reexamination of the Negative Viking Labeled Release Experiment Findings regarding the existence of life on Mars

[Robert Jastrow, a director of NSS, has proposed the reexamination to Hugh Downs, Chairman, NSS Board of Governors]

Commentary by Peter Kokh

I have one observations to make which would seem to be salient, if not urgent:

First, it *is* important to resolve lingering doubts and for this reason I support the restudy. *But no one should think for one minute that if the restudy results suggest a reversed conclusion, i.e. that there is biological activity on Mars, that then this finding would spur on crewed Mars exploration. On the contrary*, there would surely be a strong upwelling of support for what in my mind would be a misguided proposal to make Mars and its microbes off limits to Mankind - forever.

I remember my own initial disappointment when the negative results were first announced. It was followed *within seconds* by an opposite overwhelming elation - the realization that *if there was no life on Mars, then Mars was clearly ours, ours by default*. Keep that in mind!

PK

[Series Continues]



Part III: Off the Beaten Path

by Peter Kokh

What about Lunar communities outside the land-grant peripheries of the major settlements, and outside the land grant corridors of pipeline and inter-settlement road-construction companies? Will these unincorporated, unincorporated reaches remain empty? If not, how will any pockets of humanity therein survive and earn their keep? Our subtopic this month.

BACK READING: "Rural Luna" in MMM #15 MAY '88.

[Republished in MMM Classics #2]



Tarn: [tahrn] (ME *terne* < Scand; cf. Icelandic *tjörn*: pond, pool)

- (1) A small mountain lake or pool, such as in a closed glacier-scooped basin, often with no outlet and/or no specific inlet.
- (2) *By metaphor:* a rural lunar outpost with no regular water or hydrogen resupply (not on a pipeline or regularly serviced truck route), protective of an initial water/hydrogen endowment.

by Peter Kokh

We indulge in introducing a new term here, because the pockets of humanity we foresee under this heading promise to be rather creatively unique as human cultural institutions go. Tarn type outposts will arise sooner or later primarily to meet a number of economic needs or scientific purposes.

But a significant secondary driver in their formation may be the unprecedented opportunity they will offer for small “intentional communities” and charismatic leaders desirous of developing their own forms of cultural, religious, economic, educational, philosophical, social, and familial expression — relatively free from interference, whether intended or not, thanks to their isolation and remoteness — “off the beaten track”.

Economic niches for tarns will be many. Unique mare, highland, volcanic, and central peak upthrust mineral deposits not common elsewhere on the Moon surely rate at the top of this list. Tarns offering out of the way scenic sights and vacation experience treats for ambitious tourists in search of the extraordinary and uncommon are another likely category.

Some tarn hideaways could specialize in conducting spiritual retreats, short or long. Boarding school academy tarns could offer stricter discipline along with unexcelled education away from main settlement peer pressure distractions.

Monastery tarns could earn their keep raising agricultural specialties not otherwise available (chocolate? tea? silk? oranges?) A monastery might provide the resident everyday support staff for astronomers visiting a deep farside radio astronomy and S.E.T.I. installation.

Tarns could earn spare income by taking in individual students (both problem and gifted) from the urban settlements. Adult apprentices in Tarn specialty arts and crafts might also be welcomed. Others from the “city” could come on volunteer working vacations just for “tarn-raising” construction duty. For them, the change of scenery and life style, however temporary, could be a welcome shot in the arm.

It is likely that as the range of talents of tarn members increases and diversifies, so will their economic underpinnings. Each may also produce unique tarn-specific arts and crafts with which their names will become identified (much as do the various pueblo communities in our Southwest), all for export. Unique folk dances and costuming could appear. Tarn plants and animals and controlled climate could all be picked to offer commodities for trade to the larger settlements of items not available there. Add possibly tarn-specific architecture and interior design and furnishings. The clear upshot is that when you have visited and seen one, you will *not* have seen them all.

Older tarn youngsters might do a year or two of exchange education in another tarn. That would serve to cross-fertilize cultures and arts and crafts and, hopefully, lead to exogamy, and the avoidance of inbreeding.

On that topic, very small communities are specially prone to sexual imbalance. Unusual familial arrangements may be sanctioned in various tarns to redress this problem. [On this point, reread Heinlein’s “The Moon is a Harsh Mistress”.] Tarn children could be raised in common by all adults. Polygamy or polyandry might be encouraged. Superfamily ties will be strong.

Unique as each tarn community may be, they will have many problems and needs in common. This will surely give rise to some sort of mutual aid cooperative support association, with most business carried on over the electronic nets. The Lunar Frontier Republic may well have a special Office or Bureau of Tarn Affairs offering construction, educational, biospheric, agricultural, manufacturing, entrepreneurial, and health assistance. Hopefully such a government support office would not be a copy of our own patronizing BIA.

“Gypsy Traders” might ply the unimproved stretches between various tarns, picking up preserves and wares and artcrafts and other items for sale on consignment to other tarns and to the major settlements as well. They might offer “tramp steamer” type accommodations for tarnfolk and others seeking to get about.

Tarn life will be hard, character-forming. On Earth, those who want to be closer to nature head for the countryside. On the Moon it will be the larger settlements that will have the larger, lusher, more diversified, more soul-coddling biospheres. Yet tarn life will have its promised rewards and draw many. They will come direct from Earth, and second hand from the main settlements, too.

Our presence on the Moon will open with a single government or consortium-run outpost/settlement-to-be on an otherwise unoccupied alien world. But with the rise and spread of tarns, the Moon will become a second, adoptive home world for humanity. And the operative word here is “world”. **MMM**

RURAL MARS

by Peter Kokh

RELEVANT BACK READING: MMM #62, FEB ‘93

Picking Town Sites on Mars: Climate Considerations p. 4

Frontier Republic of Mars: Fast track to federal autonomy p. 5

Canals on Mars: from self-deception to reality p.6

[Republished in MMM Classics #7]

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

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

Geothermal sources of energy on Mars are a total unknown. Future orbital mappers may find hot spot clues. **Wind** power will work only for extremely light loads. **Solar** will play a role, but mostly a backup one, just the reverse of the likely situation on the Moon.]

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

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

Some interesting observations can be made.

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

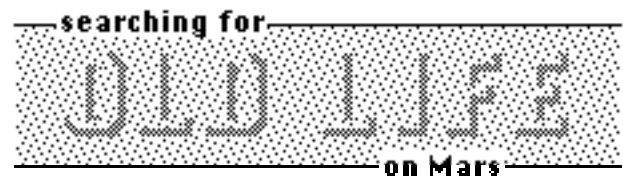
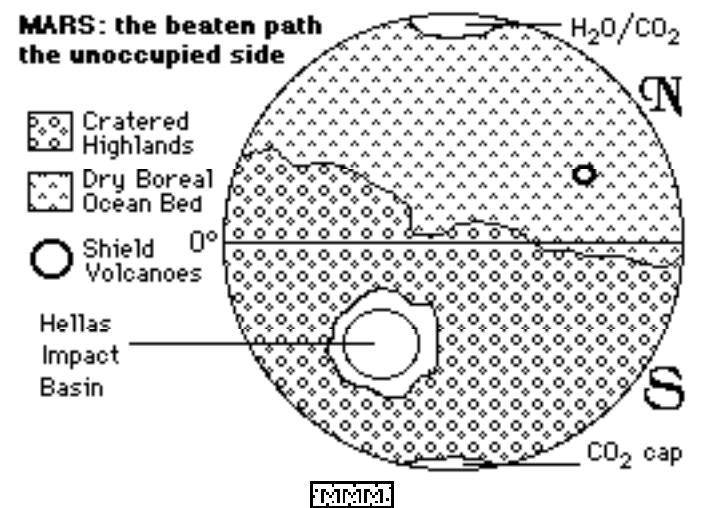
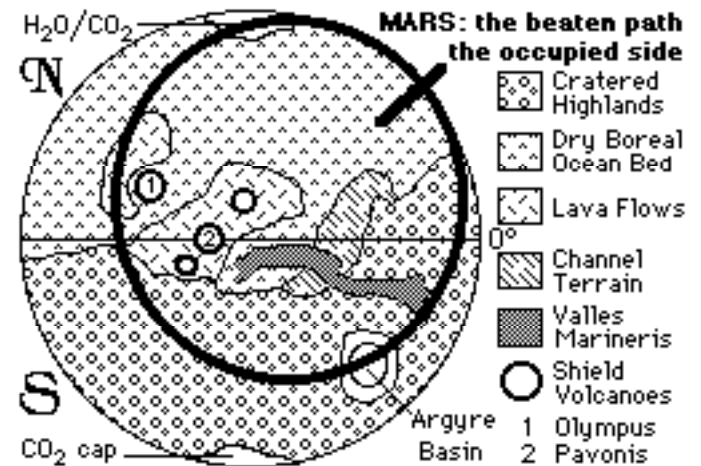
Radio is unlikely without an uninterrupted chain of line-of-sight relay stations along each route. If a network of global communications satellites and global positioning satellites (GPS) proves too expensive for the Mars Frontier Authority to purchase, install, or maintain, “meteorburst” communications,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

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

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

Rural outposts on Mars will have much greater independence as far as such basics of life as volatiles are concerned. Nonetheless, they will be as or more interdependent on one another for other goods and economic necessities. The Martian “outback” will be more like the Australian, the

Alaskan, the Siberian, and the Patagonian, than the barren reaches of the Moon. It’ll be interesting all the same.



Two different questions - Two different searches

by Peter Kokh

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

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

Time changed all that. The orbit changed along with the tilt of the planet’s axis with the result that Mars received less solar warmth, year in and year out. The planet’s gravity only three eighths that of Earth, its atmosphere slowly and

irretrievably leaked out into space with further chilling and desiccating effect. The Sun's friendly warmth was replaced by a different kind of fire, the wrath of an ultraviolet flood.

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

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

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

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

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

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

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

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

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

all of their species related to ones part of photosynthetic food chains. They could not have independently originated there.

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

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

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

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

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

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

There may be many species of such microbes, some with merely anecdotal differences, others specially adapted to rocks of differing chemical and mineral composition. If we find

them, these micro-Martians will provide a delightful and long-lasting high to exo-biologists, but will quickly bore the Hades out of the rest of us.

Implications for Martian Settlement Dreams

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

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

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

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

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

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

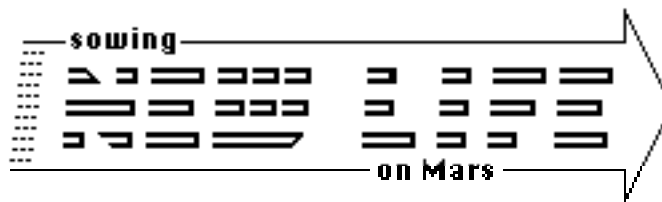
But the stubbornly persistent romantic notion that if we were to find extant native life on Mars, that it would provide the start, at least, of a food chain to support human settlement, and thereby make Mars that much more attractive to the powers that be, the ones in charge of the purse strings - this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

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

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

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

FRANK



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

GREEN MARS

Kim Stanley Robinson

Bantam Books, New York 1994

ISBN 0-553-09640-0 (HC)

Reviewed by David Dunlop, LUNAX Corp.

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

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

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

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

tion and war create. It is also clear that great economic growth in the aftermath of war occurs as a result of technology developments made for the waging of war.

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

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

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

Serious Non-Fiction on the topic

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

The Greening of Mars. Michael Allaby & James Lovelock, 1984. The authors propose that the world stockpile of CFCs be payload for the world's stockpile of ICBMs, all retargeted for Mars, where the CFCs would contribute a maximum "greenhouse effect", putting the temperature of Mars over the threshold where the carbon dioxide trapped in the polar caps would permanently melt, thickening the atmosphere to the point that liquid water would be stable on the surface and the "greening" of Mars with hardy genetically reengineered plants from Earth could begin. They see no place for animals in this scheme. The thickened atmosphere would be fine for plants but unbreathable to humans, so the latter would continue to live in pressurized habitats or domed cities.

James Lovelock had previously co-authored "The Gaia Hypothesis" with Lynn Margulis. **MMM**

MMM #84 - APR 1995



The Lunar Prospector "Team" Patch of 1989

Not a mission patch (Alan Binder's team at Lockheed will surely come up with its own design if NASA's latest Discovery Program winner escape the Sensenbrenner slash)

- the "Team Member" patch was meant to rally space advocate support and open wallets for seed money to get the Lunar Prospector project off the ground. LRS put up a \$100 prize and attempted to advertise the patch design competition nationally. All entries were taken to the Lunar Polar Probe Conference in Houston in March of '89 hosted by the Houston Space Society. Conferees selected a clear favorite, this design by Bill Burt of Milwaukee. [A few of the brightly colored patches are still available from the Lunar Reclamation Society, PO Box 2102, Milwaukee, WI 53201 for \$5 including shipping as of 1/7/06]

[Series Continues]



This month we turn to the Economic Considerations that will affect the viability of rural outposts. We begin with some speculation as to "appropriate" physical construction methods that might make "tarn-raising" more feasible.

To those joining us this issue, we are borrowing the Scandinavian term *tarn* which designates a small, isolated mountain lake with no apparent inlet, but actually fed by rain or glacial melt-water, as a metaphor for the isolated "rural lunar" outpost that must religiously guard an initial water/hydrogen endowment, sources of loss make-up being costly.

Background Readings from past issues of MMM

[Republished in MMM Classics #1]

5 MAY '87 "LunARchitecture"

[Republished in MMM Classics #6]

50 NOV '91 pp. 6-8 "Hostel-Appropriate Architectures"

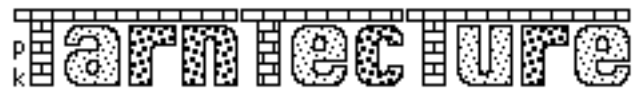
53 MAR '92 pp. 4-6 "Xity Plans"

54 APR '92 pp. 5-6 "Xity Plans, Pt. II"

55 MAY '92 p. 7 "Moon Roofs"; p. 8 "Shantytown"

[Republished in MMM Classics #8]

75 MAY '94 pp. 4-6 "Modular Architecture"



by Peter Kokh

Tarn Construction Materials and Methods

If there is to be a "rural Luna", especially inexpensive methods for constructing suitable pressurized volume from local resources must be developed. Equipment involved ought to be mobile, so that it can, construction or expansion finished, be transported to the "next" site on the waiting list.

Construction methods can be many and various. First, modular building plans seem especially appropriate. But if it becomes feasible to erect a larger common pressure shell which can be subdivided at leisure with individual structures that need only provide privacy and partition, that may prove a popular choice as well.

Fast & easy installation, cheap in both materials and equipment lease or rental, spacious with room to grow into, low-maintenance and energy conserving — these are the

desired features for tarn structure and tarn-raising. Mobile casting units for hex-flanged upper and lower dome hemispheres is one suggestion. Fiberglass-reinforced cast basalt might be a cheap enough option. Glax (fiberglass-glass matrix composites) would be more expensive. Iron in the form of an inexpensive and easy to formulate steel would be another option. A SLuGS (Seattle Lunar Group Studies) investigation showed that in the regolith excavated from a lunar habitat construction site, there are enough free unoxidized 'un-ored' iron fine particles from which to build the structure needed.

Leased or rented equipment should be mobile enough to be moved from site to site without prohibitive expense. This can be done "overland" on truck beds, or by suborbital hopper, depending upon where the next site is located, and how accessible it is.

Initially, of course, the dependence on city- (main "urban" manufacturing settlements) produced construction equipment and building products will be total. But that era should be short-lived. Quite possibly, a tarn once built and occupied, may, in order to expand at less cost, and at its own scheduling, develop modular building components of its own. This technology could then be exported to other tarn sites, either by way of the necessary capital equipment, leased technology, or simply by shipping manufactured building components ready to use. Either way, entrepreneurialism in improved tarn construction methods, equipment, and materials, should provide one or more tarns with extra diversified income.

Lego like (iron) tins to be filled with regolith (reminiscent of the "world bottle" plan which called for the design and manufacture of beverage bottles so shaped that they could be used as structural bricks), vibra-packed sinter-blocks, sulfur-impregnated regolith) block (100 times less total energy of manufacture than concrete block), are some lower technology products that suggest themselves. Mining tarns could use tailings to make building material products. Tarn building "kits" are likely to include equipment, molds, and forms for use with local materials, plus suggested plans.

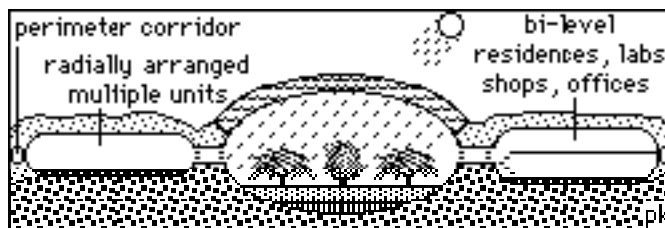
We expect that in most tarns, the accent and emphasis will be on the communal commons, on dormitories rather than traditional residences, and on the work place. This tilt would seem to favor the megastructure approach, though all of the above features can be achieved by the modular method as well. The African Kraal or Coral and the Southwest Indian Pueblo communities come to mind: translated, that would indicate a common shield wall and large commons or community square. Community life will be the strong suite of rural lunar outposts. Within the common structure, peripheral to communal space, would be residential dorms and or family or super-family quarters, work places, agricultural/horticultural areas, biosphere cycling equipment, and whatever else.

Tarns will be individually distinctive

When you will have visited one tarn, will you have seen them all? Predictably not! Tarns will differ from one another, first because their economic raison d'être will differ and be reflected both in the architecture and layout, and in the micro-culture of the place.

Second, the very brashness of their attempt to survive

and find a niche out in the lunar boondocks will assert itself by freely chosen arbitrary but highly visible architectural means. Examples? How about distinctive, eye-catching, even gaudy entrance gates? How about colored-fiberglass "thatching" over their regolith mounds, or simply a layer of colored powder? A gleaming "hydroshield dome" putting the tarn water reserves to use as light-filtering shielding over a park-like commons in a suitably sized craterlet? Or some telltale horizon-breaking structure, preferably with a legitimate function, visible for miles around? Think of windmills, silos, and grain elevators in the American countryside. Yet others, cherishing their isolation, may choose to blend into the moonscape unnoticed.



FIRMAMENT™ hydroshield domed-crater tarn commons with up to 24 'lith-shielded cylindrical modules placed radially.

SOME PROBLEMS for hydroshielded glass domes:

- √ Keeping water cool enough thru dayspan, warm enough thru nightspan: known infrared rejection coatings may be insufficient. An active dayspan heat rejection and nightspan heating system may be needed. The hydroshield might possibly be used as a heat sink for industrial activities during nightspan kicking in as temperature cools. This would reverse more conventional operations scheduling.
- √ Vulnerability to failure thru micrometeorite puncture of outer and possibly inner glass: a nightspan sphincter shutter system might be required. This shutter could be withdrawn over polar facing sun-shaded portion during dayspan. It should be closable within minutes given radar warning of incoming meteorites of dangerous size. This shutter could also close during scheduled 9 hour "nights" during dayspan *if* a staggered shift system is not in use. (And a small tight-knit community is likely to reject any staggered shift scheduling option.) These measures would both decrease the vulnerability to impact accidents and reduce the total heat rejection burden.

Diversity of Niche = Diversity in Appearance

Differences in appearance will flow not only from the choice of materials and construction methods. They will also flow from the tarn's "vocation" and may be highly individual in character. There will be "family resemblances" also that advertise a group or class of tarns:

- roadside service tarns belonging to some chain or franchise operation
- mining and processing tarns
- tarns that offer retreats to city-folk
- tarns that conduct special tourist excursions to scenic attractions off the beaten path
- tarns that take in and educate students in boarding school academy settings free from urbane abstractions
- tarns that support small science communities e.g. at some giant lunar accelerator, or at a farside radio astronomy/

S.E.T.I. installation, or at a major exploration site above a complex of lavatubes, etc. e

- tarns belonging to a Lunan Farming Cooperative
- tarns belonging to some religious or social denomination or movement seeking to flower more fully well apart from the mainstream of Lunan society.

Each category will by nature express its functional and psychological needs differently. And these differences will often be quite visible sometimes from outside approaches, but sometimes only in internal layout and decor. Form follows function. Transport magically to the tarn square and you should have a pretty good idea right away what sort of tarn you suddenly find yourself in. That spicy variety will make “Rural Luna” a “world” worth exploring. For those who cannot afford to visit them in person, there will be the fascinating articles and pictures in National Selenographic. MMMM

[and speaking of exploring ...]

Ghost Towns

& *MMMS* Rf

Relics of False Starts, of Boom & Bust

by Peter Kokh

When an outpost is built, won't it be “forever”? One would think that those proposing to set up an outpost would need a permit, the application for same having to give evidence of a sound business plan and adequate initial capital and other resources - lest the new commune become a ward of the state. Oddly enough, the very first lunar outpost may not have to meet such a stringent test, especially if it is a government installation, its economic justification compromised in some committee. Thus it is the very mother of lunar outposts that is most likely to become a ruin, a place designed to “take steps” towards economic self-sufficiency “when and if funds allow.” Hopefully, however, such a monstrosity will not follow on the footsteps of S.S. Freedom or S.S. Alpha.

Yet, given a first genuine lunar settlement, soundly grounded in economic activity, with openings emerging for peripheral encampments engaged in supporting roles, *some* of these smaller hamlets will indeed fail. They will fail despite careful review, despite land grant subsidies, SBIR type grants, and despite all other reasonable assistance.

The “market” may not pan out for the tarn’s proposed product or service mix. That economic micro-niche may turn out to be temporary. A mining operation may prove to be too marginal. A crossroads location for a wayside service complex may never see the expected traffic. The crops planned for an agricultural tarn may not produce a regular profitable harvest. Tarns dependent on recruiting fresh pioneers may find their appeal too restrictive and never get the expected fresh blood.

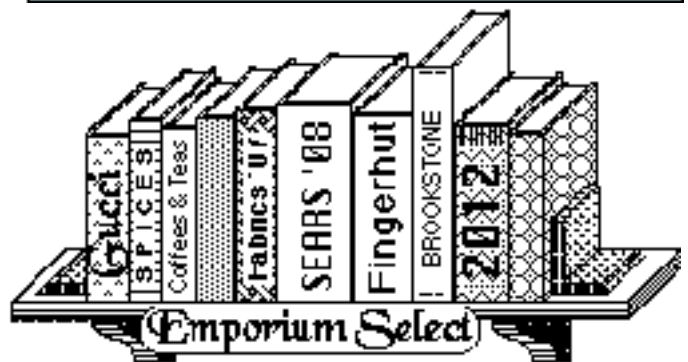
Some tarns will be abandoned during construction, others soon after. Some will do well enough for years, perhaps

even thrive, but then see their product and service mix become outdated, unwanted, behind-the-times, and be unable to adapt. A bad risk is taken in expansion. A new highway takes traffic elsewhere. Communal strife breaks out, defying reconciliation.

What will happen to abandoned tarns? On the Moon, they will hardly fall into “ruins” through mere neglect. There is no “weather” against which a “state of repair” need be maintained. There is no ecosystem that will reclaim the spot, to turn it back into forest or jungle. In Antarctica, where this is also true, and outposts and camps tend to be preserved, they still slowly get buried in accumulating snow pack. Not here.

The first risk is unauthorized plunder and canabalization by others. Baring this, a tarn once built, or even partially built, remains an investment that can sooner or later find new owners, new purpose, new life. Others can someday take over, giving the place sufficient reinvestment, and new direction. In the meantime, abandoned sites would revert to ownership by the Frontier Government. MMMM

MMM #85 - MAY 1995



Safety Valve for the “Material Girl” — and Guy

For a morale boosting safety valve, imagine a rural Luna Casino where winnings are vouchers in an on site bazaar or “Emporium” filled with imports otherwise unavailable on the Moon. They could be used also for catalog orders from Earthside specialty houses. Winners could keep or sell their booty. Such a casino could be located in a scenic area well removed from the main population center(s) by a couple of days travel. Favored items? Craft tools, bolts of fine fabrics, canned delicacies, coffees, teas, spices, perfumes etc.

This would be preferable to an all out Draconian ban on import luxuries. — More on “Rural Luna” ⇒ *below*.

Series Continues]

by Peter Kokh



This month we continue our discussion of the various Economic Considerations that will affect the viability of rural outposts. These will vary greatly according to type of outpost.

To those joining us this issue, we are borrowing the Scandinavian term *tarn* which designates a small, isolated mountain

lake with no apparent inlet, but actually fed by rain or glacial melt-water, as a metaphor for the isolated “rural lunar” outpost that must religiously guard an initial water/ hydrogen endowment, sources of loss make-up being costly.

Background Readings from past issues of MMM

[Republished in MMM Classics #1]

MMM #10 NOV ‘87 “FAR SIDE” Pt. II. The ideal site for front-line astronomy in the 21st Century”

[Republished in MMM Classics #4]

32 FEB ‘90 pp. 5-6 “Port NIMBY: Import/Export Sleeper”

[Republished in MMM Classics #8]

79 OCT ‘94 p. 15 “WAYSIDE”; “Service Center & Inn”

Way Side Tarn

In the above mentioned articles from MMM # 79, we outlined how the need to provide for periodic roadside service could lead eventually to commercial inns catering first to truck traffic, then to more casual traffic, as that arises. As on Earth, Lunan entrepreneurs, as well as some coming directly from the home planet, will be eager to gamble on a “growing market” and build individual fields of dreams, in the hope that the business will come.

On Earth, there is only the banker to act as a reality check on questionable dreams - and we all know that bankers can be very lax in their examinations. On the Moon, where rural entrepreneurial success is likely to be somewhat more difficult to realize, it may be wise to put in place a licensing screen that will both act to screen out poorly based business plans and to challenge good planers to significantly improve their proposals. Not to do so will mean a waste of resources, public and private both, that might be more wisely used.

On the Moon, the chain and franchise operations will be especially attractive, if not to would be operators, then to their financial backers and underwriters. Proven pathways to success are a better gamble. Nonetheless, as here, individuals with a dream will manage to strike out on their own, and in the process introduce new service “products”.

As a “tarn”, any rural operation will have to be much more than a Ma & Pop endeavor if it is to succeed. There is a micro-biosphere to establish and maintain, not just a motel, restaurant, and gift shop to run. The minimum critical mass population of such rural lunar hamlets is likely to be more than a dozen - perhaps a lot more. The business plan will have to take the establishment and maintenance of the micro-biosphere into account.

If a restaurant is involved, operators will want to produce locally, at least some of the food offered. If a certain reputation for the special and the unique is one of the points of the business plan’s “Mission Statement”, that suggests that the tarn gardener be planting herbs, spices, vegetables, fruit, etc. that may not be common in lunar farms.

If a gift shop is involved, besides the usual tourist trap fare offered elsewhere, tarn residents with an arts & craft aptitude will be encouraged to devote some of their leisure time into producing gift and souvenir items unique to their tarn.

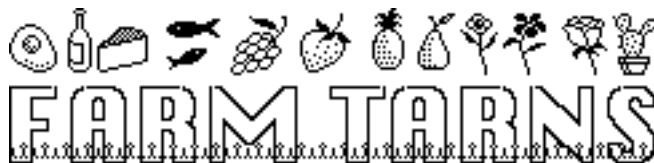
These might be based on special agricultural byproducts, on local mineralogical resources, or simply on unique talents.

Special rest period services for road-weary travelers are another way for a roadside service tarn to distinguish itself and create a high profile public image. Such services need not be limited to the fleshpot variety. Other pampering services can include whirlpools, spas, steam rooms, saunas, exercise rooms, ball courts, dancing, grooming and makeup sessions and more. Tours of the surroundings or of unique aspects of the local tarn operation can be offered. Social events in which tarnfolk and traveler can mix may be welcome to both.

Vehicle service, repair, and maintenance will be the mainstay, of course. And, as on Earth, the three most important assets of any business plan, no matter how well thought out in its other aspects, will be “location, location, location.” A place of business will have to have quite a reputation to survive “off the beaten path”, even if the detour inconvenience is minor. Special bread and butter services like warehousing or operation of a special scenic concession may or may not provide the compensatory lure.

The best locations will be at crossroads and junctions and transportation nodes; places where goods can be off-loaded from one vehicle carrier to another and transshipped; and motor coach hubs for transfer from one vehicle or carrier to another. But the busiest stops are not always the most pleasant, nor the most attractive. Some less advantaged sites are sure to thrive, as individual tarns work industriously to establish their place in the sun. Stopping en route will be as much risky fun on the Moon as on Earth.

MMM



The incentives for a group to go off and farm by themselves can be many. The “climate” of the settlement biosphere may not be suitable for the growth of the crops species one wishes to plant. One may want a climate that is colder, or is subject to periodic frosts, or is more tropical, more moist, even more dry. While special climates can be effected in semi-separate parts of a main settlement, it may be simpler to have total separation. Quite likely, the practitioners of one type of farming will want themselves to experience the proper temperate, subtropical, tropical, or arid climate in their own habitat area common spaces, not only just in the farms. After all, climate is interwoven with culture as well as with agriculture. That is the total experience everywhere on Earth.

Perhaps also, it is zoning and land use tilts that do not favor the farming or horticultural methods one wishes to use. The settlement, for example, may have a decided tilt toward hydroponics, as it is more stingy in its pressurized space demands. This may not sit well with those determined to try a regolith-based analog of more traditional farming needs.

Plausibly there will be a need to quarantine some crop specialties from others, reducing risk of transmitted blights, pestilence, and disease. That works both ways, of course, and the settlement may put out the ‘not welcome’ sign at the same

time as would-be rural farmers declare their own intent to sequester their chosen crops.

But there may well be non-germane motives at work. Many brought up in agricultural settings on Earth will cherish the rural experience and not want to be a “part” of the “Xity” experience, however large an agricultural operation the larger settlement needs to have as an integral part of its biospheric underpinning.


All this said, there remains (a) the need for any outpost to be an integral human community engaged in a full spectrum of self-supporting activities, of which farming will be a significant part within a range of limits; and (b) the fact that other activities seen as farming-compatible may have more specific location requirements and constraints than the major or minor farming operation. Thus, there is no reason not to combine farming with road service, or farming with science outpost support, or farming and mining operations. Unless, of course, the tarn founders seek isolation as an end in itself; and provided too, that such founders are successful in recruiting enough compatible pioneers to follow them.

Serendipitously or by dedicated search, some locations will be found in which the “soil” as raw, unevolved, and unweathered (by water and air) as it is, is so much more favorable to certain desirable crops as to warrant the establishment of a farming tarn operation even when the site lends itself well to none of the other suggested co-operations. Such out-of-the-way farm tarns will succeed only if the bottom line domestic/lunar and/or export/space demand for the crop in question is sufficiently large to underwrite all the bills. If despite this burden, a remote farm operation succeeds and thrives, it may become a magnet in its own right, attracting trade and traffic and other differently oriented outposts. The symbiosis and partnership of farm and village is age old. On the Moon too, they will thrive together.

As suggested, lunar farms need not justify their operations in the lunar market alone. Almost any food grown on the Moon with lunar oxygen and many lunar-sourced macro- and micro-nutrients will be cheaper to purchase in any space place, even Earth-hugging low orbit, than food raised on the Earth’s surface, no matter how much more cheaply and efficiently, but brought up the steep gravity well at high fuel expenditures. Only special delicacies or treats available from Earth alone will make it onto space pantry shelves and into space eatery menus.

Special export and domestic crops overlooked in tightly planned and eco-balanced settlement biosphere farming operations could include Coffee, Tea, Spices & Herbs; fruit and vegetable specialties; supplementary meat producing animals and animal products; additional fiber producing plants; pharmaceutical feedstock plants; dyestuff plants; and more.

Almost any farm operation will earn income from a visitors’ greengrocery as from a shop selling recyclable wares made from agricultural byproducts. Almost any farm too could offer an in-farm picnic and R&R spot for travelers.

Farm tarns will not only add to the total biospheric mass in place on the Moon, they may become a key player in the Moon’s drive for economic autonomy and self-sufficiency. The “civilizing partnership” will continue. 

Mining Tarns

The Moon is much more “homogeneous” mineralogically speaking, than is the Earth, not having undergone the eons of hydrotectonic geological processing that resulted in most “ore” veins on the human home planet. The percentages of the big seven (oxygen, silicon, aluminum, iron, magnesium, calcium, and titanium) vary within general ranges that would allow an industrial settlement to locate in most any “coastal” location from which both highland and mare type soils can be easily accessed. Titanium is the major exception to this rule.


Nonetheless, specialized mining operations that exploit relatively small abundance differences are sure to arise once the market for their mono-products are sufficiently strong. Entrepreneurial exploitation of unique mineral resource endowments, however, will not be limited to the big seven. As the industrial economy on the Moon slowly diversifies, the need to produce elements present in lesser abundances will give rise to scattered operations in many places.

In general terms, some of these special sites can be predicted. Foremost will be polar permashade water-ice fields if indeed such comet-derived deposits exist. Then there may quite atypical Sudbury type asteroid-impact derived endowments of nickel and copper and other useful metals. They await discovery and are conjectural at present.

Crater central peaks are likely to be composed of mantle upthrust material that may be enriched in aluminum over common highland abundances. And here and there are fields of the so-called KREEP deposits (“potassium, rare earth elements, and phosphorus”) such as those from the splashout of the Mare Imbrium basin forming event.

Apollo Orbiting Command Modules 15 through 17 were equipped with gamma ray spectrometers which scanned the equatorial regions. Among other things, they found scattered traces of Thorium which might indicate the presence of lead and uranium as well. There will here and there be found other atypical concentrations of economic value, including possible gas trap reservoirs of minor or major importance.

Locally owned mining “tarns”, as distinct from non-family based “company” operations, will want to preferentially ship **value-added processed products** and manufactures. So they should become critical nuclei of industrial villages or settlements. Of course, they will need to be into farming too! And unique mineral-based arts and crafts are a certainty.

Mining tarns will be part of the rural triad that turns the Moon from a one-town rock into a “world”. 

The Lunar Jumping Jeep

© 1995 J.H. Chestek, Philadelphia Area Space Alliance

How will the early lunar settlers get around, say from Armstrong Base, to Kennedytown, to Water Mine #1? The only surface lunar transportation used thus far by the human species is walking or wheeled cars. The lunar rovers used had a very slow speed and a very limited range. Further, they were limited to reasonable flat terrain. Hence they are not suitable

“Good things come in small packages”

for traveling between sites a few hundred miles apart.

Much later in the era of lunar settlement, when we are talking about routine travel between cities, we can either build highways or railroads to facilitate high speed travel. But in the pioneer days, we need an intermediate solution, a "lunar jeep."

We need an off road vehicle that is suitable for traversing the very rugged lunar surface at a reasonable speed. The low gravity and the vacuum conditions suggest an interesting possibility, a jumping vehicle that leaps from place to place across the terrain. This will enable it to go over large boulders in its path, climb into / out of giant craters, or bound over deep crevices. Further, it should be quite economical on energy consumption, permitting substantial travel with one refueling.

This author proposed such a vehicle in the early 1960's, believing the idea to be original, for a tiny lunar rover to be carried to the moon by Surveyor. As is often the case, it was later learned that the same concept had been proposed previously; in this case by none other than Hermann Oberth. He wrote a book in 1959 called "The Moon Car," which described a much larger manned vehicle that could either roll along, or jump over obstacles. The principles described in that book are sound, but the advent of microelectronics has opened up control possibilities not foreseen by Oberth, making the concept even more practical.

For a manned vehicle, the limit to the jumper's capabilities is limited by the amount of jump acceleration the crew can withstand. Assuming that a human crew is willing to withstand repeated jumps at three gee acceleration, then a vehicle with telescoping legs that can extend 18 meters (59 feet) with that force, then we have a vehicle that can jump four tenths of a mile at a time. When leaping for maximum distance per jump, such a machine will spend about thirty seconds on each such jump, and will soar over five hundred feet into the lunar sky at the peak of each leap. Tall buildings at a single bound, indeed!

Moreover, the energy consumption of this machine will be small, assuming only that the lunar soil will remain compacted after it has been jumped upon a few times. The energy used to make one jump can be recovered by the telescoping legs upon landing. Then the only losses are the friction in the leg extension and retraction. (There is, of course, no air drag.) If these losses are only 1% of the energy needed for each jump, then an ordinary automobile battery (of 200 ampere-hour capacity) would store enough energy to take a one metric tonne vehicle a few hundred miles. And of course, aerospace batteries are even lighter than car batteries.

Assuming that a pioneer has already scouted the terrain, so that you have a "digital map" to exactly plan each jump in advance, then at the rate of a jump every 30 seconds, you can travel at 48 miles an hour. If the path has not been surveyed ahead, then you will need to go more slowly, so you can examine each landing site as you approach it, and manually determine the jumping commands to lead you to a safe landing.

There may be a business opportunity here for a daring entrepreneur. The same principles will work on Earth, although each jump will be six times shorter and lower. What a carnival ride such a machine might make! You will have a solid patent position when the time comes that we need jumping machines for the serious business of lunar settlement.

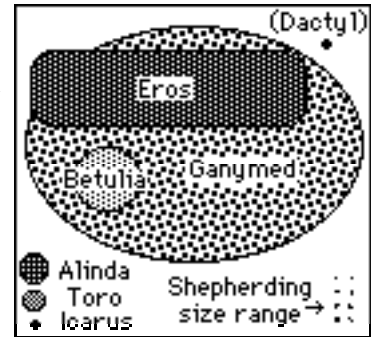
JC



[left] A *Galileo* Photo of asteroid 143 Ida's moonlet **Dactyl** - the smallest inner system body yet to be imaged, about 1 km (3200 ft.) in diameter. The spring '94 photo resolves features as small as half a football field. The find was a surprise.

[right] NEO (near Earth object) size range and shepherding size ranges in comparison. The biggest and brightest asteroids venturing within the orbit of Mars were discovered early.

Now, dedicated concerted efforts with very sensitive cameras and new tracking devices are finding many interesting smaller objects, in handy "orbit-movable" sizes. But for a "reality check," read *below*.



Tapping Near Earth Asteroids: Time for a REALITY CHECK

by Peter Kokh

The intellectual tribalism of space advocates never ceases to amaze me. Our numbers sort out into rabid Moon Onlies, rabid Asteroid Onlies, and rabid Mars Onlies. What can possibly lie beneath the *need* to "dismiss" alternatives and options *by which one is not personally captivated* - except intellectual insecurity and emotional immaturity? Beats me.

We are blessed to be situated in a Solar System with diversified assets. We have a natural mineral rich satellite, The Moon, and it is a major body, not a token. We have a rich Asteroid Belt of planetesimal debris that is itself handy, plus a considerable list of asteroid strays that are even handier to access. Of three other "terrestrial planets", we have one, Mars, whose climate and environmental conditions lie not too far beyond the limits of experienced home planet extremes. It would be stupidly self-limiting not to access *all* these assets. Yet the "Onlies" of the various tribes would have us do just that, each in their own way. What right have any of these to limit mankind's future so?

Today our subject is not the fundamentalist nonsense of either the Moon Onlies or the Mars Onlies, as ridiculous as each is in its turn. We want here to put into perspective the valid points made by (near Earth) asteroid fans, reigning in the ungrounded exaggerations which come from their refusal to consider the trade offs that will apply. For disadvantageous

trade offs come with every asset, with every fork in the road. Isn't that just the common universal experience of everyone?

BASIC CLAIM: It takes "less round trip fuel" to reach near Earth asteroidal resources (than it does to tap resources on the Moon)

For some near Earth objects, this is certainly true, and this is an important consideration. But as an advantage, it has limits within which it is overriding, beyond which it is outweighed by drawbacks and trade offs, and in effect irrelevant. In other words, it is an advantage with a price.

LIMIT ONE: The "Less Fuel Argument" is of major consequence in **unmanned robotic missions only**, whether exploratory only, or involving telerobotic resource recovery. **Fuel is not the only payload of consequence.**

For manned missions (where crews are needed to effect mining, processing, shipping, and resource recovery in general) fuel savings pale into insignificance in comparison to **a far heavier burden of life support consumables**. On the Moon we can derive at least the oxygen locally, and grow some needed food (savings again from incorporating local oxygen which is about 50% of all organic matter by weight). In contrast, on a long asteroidal mission all consumables will have to be brought along for the journey out, and the amount that can be tapped on site for the stay on location and for the journey back may be limited by the need to apply all available manpower to resource recovery.

LIMIT TWO: Missions to Near Earth Objects are by nature singular, not repetitive, ruling out resupply and growth.

For sustained human missions, another drawback to the asteroidal option is that the travel times and infrequent windows involved **make resupply, reinforcement, and rescue virtually impossible**. On the Moon, an industrial base can start out small, then grow and diversify naturally, logically, and opportunistically. Travel times are short, launch windows are frequent (when push comes to shove, the lunar window is *always open*). A mining outpost or shepherding operation (bringing back an astrochunk to Earthspace for handier processing) must take along all the equipment and personnel and supplies it will need for the duration, even though most of it/them may not be needed until later. This flies in the face of the modern business revolution based on "just-in-time" resupply and inventory management.

LIMIT THREE: Near Earth Asteroids are each *individually* **objects of infrequent opportunity only, and not regularly accessible** — by any stretch of imagination.

This is a consequence of orbital mechanics, the laws of which are a subject very poorly understood by most space advocates. Simply put, the closer in period (an object's "year") to Earth, i.e. *the closer* an object's orbit is to Earth's orbit, *the longer* the mutual synodic period *between* launch windows. For example, you can leave for far Jupiter every 13 months, for much nearer Mars only every 25 months, for many near Earth asteroids, *only every decade or so* — for the Moon, *at any time*. We DO NEED Asteroid Resources - **But!** **PK**

[Series Conclusion]

by Peter Kokh



To those joining us this issue, we are borrowing the Scandinavian term *tarn* which designates a small, isolated mountain lake with no apparent inlet, but actually fed by rain or glacial meltwater, as a metaphor for the isolated "rural lunar" outpost that must religiously guard an initial water/ hydrogen endowment, sources of loss make-up being costly.

Science Tarns

Selenology/Prospecting Field Camps -
Lavatube Exploration Camps - Physics
Labs & Accelerators - Optical & Radio
Astronomy Observatories - Experimental
Agriculture - Biochemistry Labs - Toxic
Waste Storage - Nuclear Waste Storage &
Energy Recovery - Experimental Genetic
Engineering - Disease Control & Biolog-
ical Agent Quarantine - Historical
Preservation & Archiving.

There are several kinds of scientific activities that we will want to undertake on the Moon, and many of them can be done better in isolation from (relatively speaking) major population centers. Others of their very nature will demand an isolated "rural" location. There is plenty of room for physical isolation on the Moon, and the virtual biological quarantine enforced by the Moon's lack of an atmosphere or hydrosphere is an invaluable asset for experiments that would otherwise involve risks with serious downside consequences.

Much field work remains if we are to understand the Moon well. Selenological Field Stations may be temporary and movable. A camp at an entrance to a multi-tier maze of intact lavatubes on various levels might be in use indefinitely. Deep shafts will core mare layers and sample mantle upthrust material in crater central peaks. We'll search for Sudbury-like strikes of strategic ores of nickel, copper, platinum, and the like. Some of such prospecting field camps will evolve into permanent resource developing settlements playing a major role in the diversifying interdependent lunar economy.

Extensive areas of flat unencumbered real estate will attract gargantuan accelerator projects dwarfing the aborted SCSC. For maximum shielded cosmological labs monitoring neutrinos etc. the cooler lunar interior will permit much deeper shafts before residual crustal heat becomes a problem.

Optical Observatories and truly giant interferometers can be sited most anywhere. Those at higher northern and southern latitudes will be able to pursue unbroken dedicated around-the-clock study of major circum polar objects, like the Magellanic Clouds. Radio Astronomy installations will need to be located in Deep Farside (Mare Ingenii's large flat-floored Thomson crater seems most ideal). Those installations that require considerable support may work toward localizing such support giving rise to small settlements engaged in food pro-

duction, specialized fabrication shops, and maybe even sporting small universities or institutes and conference centers.

In Rural Luna, experimental farms will operate without fear of blight or pest or pathogen exchange with settlement biosphere food production areas. Larger scale trial biospheres could evolve into Lunar National Parks, becoming major tourist attractions for Lunans, if not for spoiled terrestrial visitors. Such forested and meadowed rille-bottom oases could support wildlife observation, camping, hiking, boating, riding, fishing, even simulated sport hunting.

This same hard quarantine will be ideal for otherwise potentially dangerous genetic engineering experiments, that nonetheless will inevitably shed light on who and what we are. Perhaps the same isolation may be advisable for riskier aspects of brave new world nanotechnology development.

Nuclear waste storage would benefit from the lack of ambient atmosphere and hydrosphere. In rural Luna, we can experiment with harvesting both energy and useful materials from such wastes. The same goes for biological and chemical toxin storage and experimental processing labs. [See MMM #32 FEB '90 pp. 5-6, "Port Nimby: Export-Import Sleeper" - Republished in MMM Classics #4]

Another less obvious but in the end incomparably more important kind of scientific activity ideal for Rural Luna is the establishment of a disaster proof repository or Grand Archives of all humanity and human history, and of Gaia: life on Earth. Despite our best efforts, we are continually losing irreplaceable human treasures and natural history collections to war, criminally misguided fundamentalist purges (Library of Alexandria, the Mayan Codex), floods (the Arno in Florence), fire, hurricanes, tornados, acid rain and just plain rot.

Lavatubes on the Moon have already survived billions of years intact. They offer cold supervoluminous "lee" vacuum unexposed to the cosmic elements. Could anything be more ideal? Here we could build the ultimate repository safe from mischief as well as accident; quarantined from biological attack; safe from the glaciers that will sooner or later wipe clean the slates of Canada, Scandinavia, much of Northern Russia and the Northern U.S.; safe from eventual demolition by geological and tectonic processes; relatively protected even from chance killer asteroid impacts. Such a vault should long outlive our species and be available for the inspection of visitors from other surviving worlds millions, even billions of years hence. If it's ultimately immortality that we seek in space, such a lunar lavatube archival repository ought to be rallying priority number one.

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In addition to those activities which need or might benefit from a certain amount of isolation and quarantine, there

are likely to be rural population pockets which have sought and continue to rigorously cherish isolation for purely social reasons. They pursue some "way of life" dream or vision.

These are the "Intentional Communities" driven by some religious (not always fundamentalist nor cultist), philosophical, economical, or purely sociological need for "purity". Founders and followers seek relief from interference and distraction, from the need to compete with more tempting and easier alternatives in undisciplined pluralist mainstream societies.

We should not assume all such efforts are misguided, though history has shown that most of them end up in failure, and not always for reason of breached isolation. There do remain social and economic and political and other institutional experiments arguably worth pursuing but which cannot germinate or bloom, much less hope for harvest, in the midst of free form anything-goes society.

Many in the "movement", especially fans of Space Colonies (Settlements), admit to having been attracted to the space frontier precisely for the opportunities of intentional community so enabled. Rural Luna should beckon them too.

Monasteries are undeniably out of fashion, if only because both celibacy and deliberate poverty are out of vogue. But these days in the age of AIDS, contempt for celibacy is noticeably on the decline. In this new climate, the reappearance of communities of monks choosing a life of quiet isolation is possible. Like those who have blazed this trail before, they would devote their sublimated sexual energies to routine and other tedious labors of love seeking some form of communion with the transcendental. Such a life offers few compensations of common appeal. Yet for monasticism to thrive anew, there is no need to appeal to the many - only to a sustainable few.

Some activities in Rural Luna would seem ideal for future practitioners of the monastic way of life. Operation of a Grand Archives of all Humanity and Gaia; or running experimental farms (and vineyards); or operating a Port Nimby ("Not In My Back Yard") type facility; or supporting a Deep Farside S.E.T.I. installation listening for whispers from possibly wiser fellow soul mates in the larger Cosmos.

Deep Farside locations with skies oriented toward the Universe-at-large and averted from Earth and its electronic relay 'noise' will be especially conducive to this life choice. Here lie vast expanses of endless peace, quiet, freedom from distraction.

Might the time not be ripe for a precursor monastic operation in Antarctica? Here is a less "threatening" way to establish pockets of humanity on that virgin continent-on-a-pedestal. A monastery could explore environmentally benign, low-impact forms of site-rooted self-reliant economic activity. In addition to Antarctic-appropriate agriculture and resource harvesting, monks could earn credit for needed import resupplies by tedious tasks in danger of being abandoned in budget crunches (e.g. Planetary Science Data Reduction.)

Or they might offer alternative resting spots for those seeking an option to burial or cremation. In the cold dry air of Antarctica, open air burial under the stars is possible. Such a "desiccatorium" could provide glass canopies to greatly retard blackening from ultraviolet and cosmic rays, with durable side

netting to thwart the sky-patrolling carrion-feeding skuas.

We do not stray. There are many less attractive backwaters on the space frontier that may go wholly undeveloped except for special societies like monasteries. [Or prisons! See MMM # 35 MAY '90 p 3. "Ports of Pardon" - Republished in MMM Classics #4] The Moon is big enough for options like these. [M:M:M]



by Peter Kokh

We all learned when we were tikes that the Moon keeps one and the same face forever turned toward Earth, that there is another hidden side forever hidden from view - until the Space Age, of course. It is not a 50-50 split. The Moon's orbit around Earth is eccentric, swinging between a monthly close approach about 220,000 miles out and a monthly far point about 260,000 miles out. As it does so, its axial rotation which is locked to its orbital period, first lags behind its orbital progress as it speeds up approaching the near point (perilune) and then runs ahead as it slows down approaching the far point. The result is an apparent wobble or libration that allows us alternately to peak 6° or 7° around either side. So in fact, only 41% of the Moon is always visible from Earth, and 59% is at some times observable. The remaining 41% is always averted. The 18% limbland areas might be dubbed The Peek-a-boos.

This apportionment will change effectively if we put relay satellites in the gravitationally stable Earth-Moon no man's lands of the forward (L4) and/or following (L5) Lagrange points co-orbiting the Earth in formation with the Moon 60° ahead and 60° behind the Moon, respectively. Such relays will allow us to "see" or communicate with the pair of 60° orange slices of Farside flanking the visual limbs, leaving the central 60° still out of touch. The same orbital libration will work to trim the *always-out-of-touch* "Deep Farside" to about 45°, a mere but all-important 1/8th of the Moon's surface.

While this area *could* be served by another relay in the L2 Lagrange position some 40,000 miles behind the Moon, the considerable, unduplicatable, irreplaceable, and invaluable radio silence of this Deep Farside area will make that choice unthinkable. We *need* that sheer undisturbed radio silence both for advanced radio astronomy installations and for S.E.T.I. observatories [radio Search for ExtraTerrestrial Intelligence].

Rural Luna outposts and towns in "Relayside" will be no more isolated from Earth than Nearside communities. As to the absence of Earth in their visual sky, it is only fair to point out that Earth is also somewhat "out-of-sight-out-of-mind" in central nearside where it is very high above the horizon. (Thus the nickname of The Crooknecks for central Nearside.)

Outposts in Deep Farside, however, can only hope to remain in regular touch by cable to antennae in Relayside. The expense of laying cable (or a chain of laser-repeating towers?)

will work to confine such outposts to narrow corridors leading to installations that by nature can *only* be in Deep Farside (the radio astronomy and S.E.T.I. installations just mentioned).

Relayside and Deep Farside pockets of humanity will have one psychologically binding glory in common, however. The absence of Earth above the horizon gives this area the most spectacularly star-spangled, Milky Way-blazen nightspan skies in the inner Solar System. [M:M:M]



by Peter Kokh

Look up "world" in any dictionary and you will find a dozen or more definitions for each of many uses of the word. None of these goes to the essence of the concept, however. It is precisely that we find ourselves "too close to the trees to see the forest". If I could take a stab at it, I might define "World" as a **polycentric horizontal continuum**, or perhaps as a functionally integral ecosystem of communities.

The point is that our sense of "world" is not that of a physical place *centered in ourselves - or in one local village - or in one settlement*. Until there is a plurality of centers of activity on the Moon, however humbly small each is taken by itself, the Moon will be a "world", in the human sense, only potentially. A "world" is a "world" *because it is shared*.

Will the Moon ever become another "world" for man? Or will it remain just a big rock with a token garrison? Not to wonder! The wellsprings of a plurality of settlements and rural outposts is clearly present in the raw physical endowment. The nonuniform distribution of mineral resources, the diversity of terrain, the special advantages conferred by grid location (e.g. polar, limb, equatorial, and deep farside sites) irrespective of mineralogical assets will all work towards the rise of multiple outposts and towns.

In addition to this distributive logic imposed by the economic geography of the Moon itself, there is another equally compelling logic within human community that will work to bud off additional settlements and outposts from the historic first beachhead. Only a plurality of towns will offer the political freedom that can only come from having options, the freedom, so to speak, of being *able to vote with one's feet*, by moving somewhere hopefully more congenial. With this divide-and-multiply inner compulsion will come institutional and cultural variety. Further, there will be the opportunity to pick different biospheric climates, flora and fauna, different urban plans, different architectures, and so on. And that brings us to elucidate yet another intrinsic parameter to the meaning of "World". A world is a continuum of places which are distinctively different from one another, not just by virtue of "nature" but especially as a result of human-added features.

With the multiplicity of human communities of whatever size comes an important "gain", that of *distributed* vulner-

ability for the population at large. No matter what disaster, natural or man-made may befall any individual human clustering, the "World" goes on. "World", then, also has the definitive connotation of overarching immortality - towns can come and go, not just people, but the "World" goes on.

"World", then, also connotes a certain inexhaustibility of relief from the local, the overfamiliar, the entrapment potential of any one particular nucleus of humanity. "World" is a continuum that includes a multiplicity of temporary or permanent escapes from one's own horizontal valley. "World" is a continuum of changing scenery, both natural and post-human. It is a whole which includes a multiplicity of opportunities to make a fresh start. We do not always need to exercise such opportunities. Often, it is enough to know that they are there. Without that ace up the sleeve, any one place becomes a prison, elegantly walled in by the lack of anywhere else to go.

No settlement, however thoughtfully planned, can stand alone, survive alone, be bearable alone. To have any chance of long term sanity and emotional health and overall morale, settlers will need to have available changes of scenery, of ambiance, of diversion. They will need places to vacation, places with which to trade, places with which to compete.

In brainstorming human settlement on the Moon, we would be wise to take a page from nature and not place all our eggs in one basket. A frontier "World" is a place in which one can get in on the beginnings, not just an historic once, but repetitively. In a very real sense, nothing we can do can turn an outpost into a genuine settlement, until, by virtue of other companion outposts, it does not stand alone. Until the Moon becomes a "world" any initial settlement will remain an unconsummated marriage of humanity and the host physical world. In this context the concept of "Rural Luna" is scarcely a far-fetched exercise in stretching the rational for "a" lunar settlement. Until "spacefaring humanity" has achieved a "world" of interdependent space locations, on the Moon, in free space, and elsewhere, we will not have truly *left* the cradle world; we will not have established an off-planet branching of humanity *that could survive* any global disaster on Earth. We, and Gaia, will not have successfully *reproduced* ourselves, and in failing to do so, will not have *hedged our bet* on species immortality.

The habit of thinking in the preemptive singular is a recent deviation from common sense: "the" shuttle, "the" space station, "the" moonbase, "the" space agency. This deviant form of lemming-like decision making must be purged from our collective consciousness if we are to have any chance to avoid an Antarctica-like caricaturization of our space dream.

Finally, it has become commonplace in this age of exploration by robotic planetary probes to speak of "what were once just blobs of light unveiling themselves to be whole 'worlds' unto themselves." But as worlds they are still each virginal. Many see this virginity as something to be preserved. But this eons long sleeping innocence awaits the kiss that will allow each such world to *really* flower as adoptive "mothers" to Man, *and to Gaia*. It could be that this will not happen repeatedly in space, not even just once, if the official and recently reaffirmed* self-deprecation that contraceptively rules our presence in the *precursor* "world" of Antarctica extends to *keep sterile* our activities off-planet.

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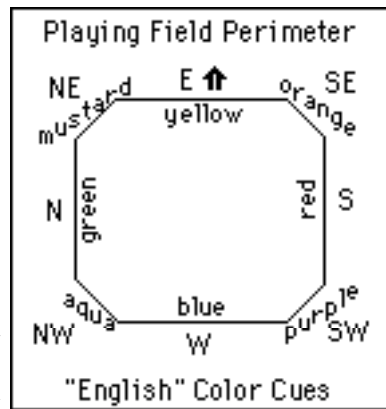
[* We in the space movement have been vigilant about the defects in the proposed Moon Treaty, even alert enough to fight lest the Law of the Sea Treaty set a dangerous precedent. But we have been caught asleep at the wheel when a few years ago, we let the Antarctic Treaty be reconfirmed for thirty years more without protest. *We may well have lost it all right there!* Remember, fifty years after Little America, all we have is McMurdo Sound, lot's of people, *none of them settlers.* PK]

MMM #87 - JUL 1995

Where N, S, E, W will mean much more than compass points

In Space Oases, hollow rotating habitats in free space, gravity is simulated by centrifugal force against the inner surface of the outer hull. In such an unearthly environment,

which way one is facing will be of more than trivial interest in sports activities of any kind. The coriolis effect (which makes drain-water, whirlpools, and hurricanes spin counter-clockwise north of the equator and clockwise to the south) will put a quite different 'english' on a ball hit or thrown eastward (=spinward) from that when thrown westward (=antispinward) or to the north (=left of east/spinward) or south (=right of east/spinward).



Space Oases sports enthusiasts will have to know which direction they are playing into and learn to compensate accordingly. One way to provide the needed cues is to color code the perimeter (fence, wall, etc.) of their playing fields so that proper reactions to different vectors will become automatic responses to these subtle visual cues. A suggestion at right is based on the color wheel - opposite colors suggest opposite compensations. ⇒ *More on Space Oases* below.

IN FOCUS Apollo 13 and Risk Acceptance, an endangered American Virtue

Commentary by Peter Kokh

We love a story with heroes. The new movie release, **Apollo 13**, amply brings this home. We are a nation starved for heroes. Why? *Because we have collectively turned off every hero-making mechanism we can find.*

We have fast become a nation of pusillanimous sissies in blatant repudiation of our past. Yet while we publicly and privately reject voluntary risk acceptance, we remain rapt and awed by examples of those who rose to the occasion of threats to life and limb that we ourselves would avoid at all cost. It is as if we know there ought to be a better side to us, as if occasional heroes collectively absolve us of our self-indulgent

cowardice. In our repressed guilt, we are a nation desperately looking for heroes, but not willing to be heroes ourselves. We want to tell ourselves we still have the right stuff. We want to glory in heroism, but only by unplanned proxy.

At the same time we reject any official policy which puts people at risk, even military personnel. We absolve ourselves by insisting that everyone follow our own yellow-backed trails. We need heroes, but they must emerge despite our best efforts to make heroism unnecessary.

We have often said that the point that government has deeper pockets than private enterprise is irrelevant when it comes to a discussion of which is better able to open the space frontier. *Money is powerless when you don't have the guts*, and the government, as the embodiment of a neurotically risk-averse society, simply does not have the ability to do what it takes - *end of argument!*

Corporate Risk-Aversion

Industries too have become intensely risk averse, unwilling to gamble on profits beyond the next quarter or two. It comes down to the *individual* or the *enterprise dominated by an individual* to push the envelope beyond the safe cozy rut. The globe circling non-refueling flight of *Voyager* illustrates the point. Burt Rutan, asked how he succeeded when by the books, this mission was impossible, replied simply 'we decided to throw away the books, and to violate accepted safety practices, and to accept calculated risks'. Of Course, the two pilots were in full accord. Sometimes you have to deliberately go out on a limb and gamble. *Voyager* illustrates the path needed to open space. In space, as with this craft, weight reduction is of the essence. When to provide redundancy and margin, weight and/or cost is inflated to the point of making the mission an economic failure, then it is time to accept a certain **triage of risks**. Some risks are cheap both in weight penalty and dollar costs to guard against, and so we guard against them. Others are marginal in penalty and cost and we prioritize them according to risk assessment analysis and do what we can and still keep the mission lean and slim. And the other risks, those whose hedging compromises the mission unduly and out of proportion, these we must accept. The Shuttle is an economic white elephant for several reasons, but failure to do any sort of risk-triage is certainly one of them.

Space advocates in many cases illustrate the adage that the apple does not fall far from the tree. In the seventies, many jumped on the Space Colony bandwagon because the vision of engineered environments promised to obviate the need to continue adapting to strange environments. Mankind's history is one long epic of one adaptation after another, and like the citizenry in "The Shape of Things to Come", we have grown collectively weary of all this adapting - *and its risks!* Space oases neatly avoid the risks of adaptation to unfamiliar and seemingly hostile environments, other gravities, other climates, other atmospheres, etc. Of course, we don't admit this motive. Instead we seize on other justifiers: unlimited real estate; room for far more people, etc. Nor do we wish to give the impression that space oases are not legitimate or that we don't need them in any full-flushed space development scenario. They are, and we do. But let us be honest about the real source of our suspiciously overdone enthusiasm!

Space advocates by and large continue to look on the government as the one who will lead us to the Promised Land - for that conviction gives individuals blanket absolution of accepting the risks of entrepreneurial alternatives. Major established aerospace contractors, like all established businesses, have become roots-denyingly conservative and risk-averse. The time for risk acceptance is youth, when we have nothing to lose and we think we are immortal anyway. This goes for personal and corporate youth.

Corporate youth means lean and small businesses still close to their roots and founding inspirations. It means finding K.I.S.S. (keep it simple, stupid!) solutions and not falling into the trap of cutting edge financial quagmires. It means accepting risk triage as a guiding philosophy.

"Blessed are the second best"

"Blessed are the second best" is perhaps the (missing) beatitude which most aptly sums up the course of natural evolution. Those best at adapting to an environment stay put; those who can't compete at that game get pushed out into new habitats, or simply fall by the wayside. Among those being pushed out, the ones who still have enough of the right stuff to deep-adapt to new environments succeed, and often go on to greater success than the stay-at-home dominants. Blessed are the second best! Individuals and young entrepreneurial outfits cannot compete on the high-priced turf of government and major aerospace contractor activity. But those who, undaunted, pioneer alternative simpler, cheaper means are the ones poised to make the breakthroughs on which the entire future will be built. Blessed are the second best. Accepting risk is the name of the game. As in any kind of investment, the safer the move, the smaller the possible profit, and vice versa.

Personal involvement and commitment

Personal involvement and commitment are instances of major risk-taking. We stand to have spent major portions of discretionary free time, even discretionary income, pursuing initiatives calculated to advance the opening of the space frontier that in the end turn out to be no more than marginally effective at best, real failures at worst. Most will not accept that degree of personal risk. And of those who do, most will be discouraged by the first real or imagined setback. Far safer to just "belong" and give "moral support", maybe even money, to some faceless organization with a committee-brokered plan. Far, far safer to limit all personal involvement beyond that level to cheering from the sidelines of the couch, or from the pages of some science fiction novel. God forbid! our lives are short enough that we should risk wasting precious free time doing something that stands a chance of not working or being ineffective! Heaven knows we don't make enough money to make ends meet as it is without risking any funds unwisely!

The space frontier will either remain forever closed except to a proxy elite feeding voyeur-addicts, or it will be burst wide open by individuals and the enterprises they start. To the degree space is a collective effort, it will be a success story of a collection of individuals, not a collection of stand-in agencies. Can it happen? It's up to a vote, and most people will be voting with their buttocks. Risk is not for everyone. But as always, history will once again be carried by the individual, the individual with the courage to embrace risk. **PK**



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Doug Armstrong and Peter Kokh

with input on alternative design options from Jeff Sanburg

It is more than two decades since the publication of Gerard O'Neill's "**High Frontier**" in which he laid out his vision for a more hope-filled future based on access to virtually unlimited solar energy supplies in space, tapped by giant solar power satellites, built affordably, with materials from the low-gravity Moon. But this was only half his vision, and as captivating as it was to many, it was the other half which lured most to join the Space Studies Institute and the L5 Society in their complementary approaches to the task of making Dr. O'Neill's vision a near term reality.

The other half, of course, is the vision of a growing number of space habitat oases to house the workers who would actually build the solar power satellites. These were the "space colonies", later amended to "space settlements" in an effort to be politically correct. Personally, we like the term "Space Oases" better, as more accurately descriptive.

The now classical space oases designs came in three general forms: sphere, torus, and cylinder, all providing, through rotation about a central axis, a level of artificial gravity, in the form of centrifugal force against the inner surface of the outer hull. These three shapes, elaborated for habitability, became the Bernal Sphere or **Island One**, the Stanford Torus or **Island Two**, and the Sunflower Cylinder or **Island Three**. In population capacity, they ranged from the low thousands to the low millions.

What attracted so many was the idea that mankind could move into space without having to settle for, or on, hostile surfaces of the worlds given us in our solar system. We could in effect start from scratch, using abundant lunar and asteroidal materials, and engineer whatever "worlds" we might want: the gravity level (1G, of course, for while space oases aficionados looked down on "planetary chauvinists" they kept to the chauvinism of Earth's gravity level), and climate. The idea that we could have large volumes of Earth-normal atmosphere, and a climate of our choice from subarctic to temperate to subtropical to tropical, was very compelling.

Further, in time there would be many separate space oases, all of them presumably single nation states each unto itself. And that appealed to libertarians and anarchists and others paranoid about the trend of infringements on liberties.

There have been other attempts at space oasis design since High Frontier. Many of them have been exercises in gratuitous baroque overdesign for its own sake. Most of these efforts concentrated on interior arrangements and did not reexamine the overall classic designs. It is CCC's guiding light that good design begins with good definition. One cannot expect to take the design of space oases to the next level if one does not first reexamine their definition.

Shortcomings in the Classical Designs An Unnecessarily high threshold for construction

The classical designs mentioned have become icons in our minds, put there early on by the captivating artwork that depicted for us sweeping panoramas of their alluring, almost utopian interiors. *That* there are problems with these very same designs has escaped most. But consider! Twenty, even fifteen years ago, the battle cry "L5 in '95" mobilized our efforts. It seemed to us something, however grand, that we could do in twenty years. Had we not gone to the Moon in just eight? And now it *is* 1995 and we are no further than those first paper studies and the color artwork that soon reinforced them. Why?

Sure, the space program has been beset by detours (we are not getting Von Braun's Space Station after all, but some politically designed chimeric committee construct which is anything but a stepping stone back to the Moon and Mars), slowdowns, stretchouts, cancellations, and indecision. But that is not the whole story.

Okay, Solar Power Satellites themselves are still an immature technology, not quite ready to go, even were we by now back on the Moon, and already skilled in producing the requisite building materials from more cheaply transported lunar and asteroidal resources. And not to forget, the seemingly intractable problem of high cost to orbit would alone arise to thwart all efforts even if everything else were ready to go.

But that is not the whole story, not by a long shot. The perhaps unconsciously suspected but unvoiced problem with the classical space oases designs is that they have a very high threshold for construction. Is this very high threshold necessary or inescapable? Copernicus Construction Company is quite convinced that it is not, that alternate designs are possible which require less epic construction efforts, therefore which should be considerably less intimidatingly expensive to undertake, and which through staging, seem capable of leading to earlier "first occupancy", and earlier return on investment.

The classical designs seem wed to a premature and unscientific determination that only a 1G gravity level is acceptable

O'Neill originally thought that a rotation rate of three times per minute would pose no problem for the general population. This is important, because space oases will be inhabited, after all, not by highly trained astronauts, but by construction workers and their families, by farmers, by merchants, and by people from just about any walk of life. At 3 rpm, a structure radius of 1,000 feet (300 meters) will provide the Earth-normal standard of gravity in which our species' physiologies have evolved.

But subsequent testing seemed to indicate that dizziness would affect a large percentage of people at that rate, that a rate of 1 rpm would be more generally tolerable. At this slower spin rate, the structure's radius would have to balloon by a factor of three to provide that same familiar and comforting 1G gravity level. That meant that O'Neill's designs would have to be upscaled by a linear factor of 3, an area factor of 9, and a volume factor of 27. Translate this into amount\$ of materials, some scaling up by 9 times, others by 27 times, and you see the beginnings of a gargantuan problem.

This fact should have led to a reexamination of the

original unstated premise, that an Earth-normal gravity level was both desirable (most comfortable) and probably necessary to maintain physiological health. But the people running with the space oases idea were by and large a self-selected group contemptuous of the previously prevailing belief among space advocates that humans seeking to settle the solar system at large would have to adapt to unfamiliar, if not downright hostile conditions as we found them. Dr. O'Neill himself is responsible for cultivating this brand of terrestrial chauvinism. Like its religious predecessors, this brand of terrestrial fundamentalism found many new converts among those for whom the older ideas exercised no appeal. Ironically, proud to belong to a new breed of "enlightened" ones, they adopted as a battle cry, the branding of those who counseled doing what life has *always* done, adapt, as "planetary chauvinists".

But back to the point. We know that the human physiology deteriorates substantially in the zero-g environment of low Earth orbit. We have ample evidence of that with many an astronaut who has spent months (up to fifteen) in Mir and other orbiting habitats. It is a colossal and extremely unjustifiable jump from that fact to the dogmatic conclusion that nothing but full Earth-normal gravity will do.

The only other level of gravity humans have ever experienced for any length of time is the one-sixth G of the Moon. But no one has spent enough time in that environment or in its simulation (NASA *will not consider* engineering artificial G environments in orbit) to provide any data points on what happens to humans at that level of reduced gravity over the long run. Now it is reasonable to assert that say the 3% G of Ceres, the largest and most massive asteroid, might as well be zero, physiologically speaking, because at that level muscles are effectively unchallenged and the friction within blood vessels and arteries may have a counter effect of comparable magnitude. *But 1/6th G is probably physiologically significant.* That is, it is not unreasonable to presume, pending hard evidence still not in, that in a *lunar like* environment Earth-nurtured human physiologies will deteriorate only up to a point, before then leveling off at some stable, maintainable plateau that may work well enough for a high percentage of the general population.

The longer we delay taking the plunge and providing a large enough rotating environment in orbit to simulate the accumulated effects of reduced but still substantial gravity over time, the longer partisans on either side will continue to base everything on wholly inadequate evidence. In this light, the silence of the space-advocate lambs before NASA's refusal to take the engineering plunge is the stuff of which tragedies are made. Much lies in the balance, not just for unrepentant planetary chauvinists like the writer [PK], but perhaps even more so for space oases fans.

It's simple really! If a sustained 1/6th G environment proves to be quite acceptable for a general population, that means that a so-configured space oasis can be downscaled by a linear (radial) factor of 6, an area factor of 36, and a volume factor of 216. In comparison with O'Neill's original presumption, that's still a downscaling of radius by a factor of 2, of area by a factor of 4, and of volume by a factor of 8. If we can accept such a paradigm shift, space oases suddenly become

much more "constructible", much more fundable, much less expensive. This shift in thinking will probably prove unacceptable to those O'Neill groupies who joined the space oases bandwagon because they could find therein a place for themselves in the universe at large that did not mandate adapting to the unfamiliar. This should not deter the rest of us who see space oases as a desirable and necessary form of space development in support of a human economy expanded by off planet material and energy resources.

If the lunar gravity standard proves sustainable for humans, we predict that it, not the terrestrial standard, will become the standard of a spacefaring civilization throughout the Solar System. Lunar-like (in this respect, at least) space oases will still be visitable by terrestrials with no intent of permanently relocating. For those assigned there (or on the Moon, for that matter) wanting easy readjustment when they return back home, special centrifugal gym facilities will let them maintain their "terrestrial muscle tone".

What in fact would this lower gravity standard mean for space oases? Structural members which constrained the centrifugal force of the space oasis need be correspondingly less strong and massive. The square footage, at the correspondingly lower radius, would be lowered by a factor of 36 affecting the amount of outer hull materials and shielding needed. The volume of atmosphere needed to fill the interior would be reduced by a factor of 216, an especially welcome savings in the amount of nitrogen that probably will have to be expensively upported out of Earth's gravity well. These figures apply to the designs as is, otherwise unchanged in their aspects and features. As we will see, there are further ways both to lower the threshold of first occupancy, and yet provide for larger populations later.

Even a finding that a more Marslike gravity level (3/8ths G) was preferable would reduce items that scaled with the radius by a factor of 2.6, those that scale with area by a factor of 7, and those that scale with volume by a factor of 18. These more modest savings are nothing to sneeze at and we predict a number of space oases with Mars-level gravity will be built both in Earth-Moon space and around Mars.

The Grave Matter of Gravity Level			
Space Oases	radius	area	volume
3rpm 1G	1/3	1/9	1/27
1rpm 1G	1	1	1
1rpm 1/6G	1/6	1/36	1/216
1rpm 3/8G	3/8	1/7	1/18

We've said all this before, in MMM # 13, MAR '88, "SPACE OASES" Part 6. Back at Square One: Baby Steps with Artificial Gravity".[Republished in MMM Classics #2] But by and large, the point remains untaken, and it is the Space Oases dream that suffers, to the point that many now believe it was just an idle daydream, something for some far future century's generations to play with anew. It need not be so!

The classical designs call for unitary all-at-once construction — when they could benefit from a modular approach.

“Rome wasn’t built in a day!” But fans of the classic designs, Bernal Sphere, Stanford Torus, and the Sunflower Cylinder would go against the time-honored advise in that monition and attempt to build unitary mega-monostructures that are at first way too big, then briefly just the right size, and then forever after too crowded and cramped. It is odd that people will reject the limits to growth on Earth and then lemming-like, do everything possible to reinstate those limits in a seriously aggravated form in space. Yes, those limits would apply only locally, to individual island habitats, and the space frontier young can always do what rural young deprived of local opportunities have been doing for a long time - move out and away from kith and kin. It’s time to reverse that trend!

Transferring the problems that *must* flow from any undisciplined growth, from global Earth to local outer space, is no solution at all. For an illustration of how the chickens will come home to roost if major unresolved contradictions in the O’Neillian approach to relief from the Limits to Growth are not addressed, read Garret Hardin’s “Exploring New Ethics for Survival: the Voyage of the Spaceship Beagle” (1968, 1972 Viking Press, New York SBN 670-30268-6, LOC 78-186737).

There are three red flags that should be waving in everyone’s mind on the concept of unitary monostructures. That these red flags have gone unnoticed and unheeded for two decades is eloquent testimony both to the lullingly seductive power of the artists’ conceptions of panoramic idyllic space island interiors that swept every concern, every alternative away in the mid -70s and the intractable need of many, deprived of one drug, to quickly become dependent on another.

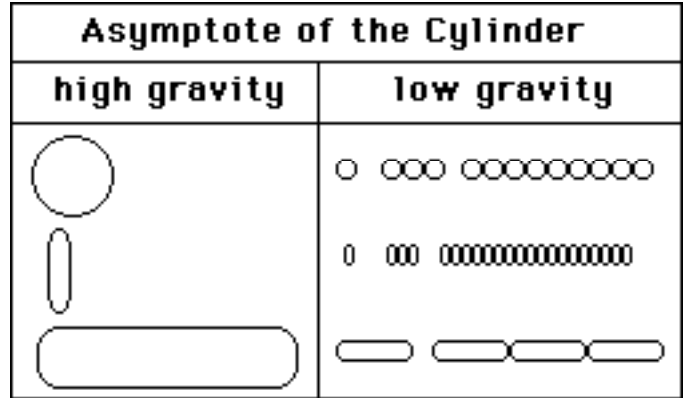
Building Rome in One Day — or Bust

The first of these red flags is the unnecessarily high funding and construction thresholds of building the whole thing at once, when with a little engineering ingenuity and modularity, phased designs are possible, one leading to the next if and when demand for space and funding availability warrant, but each of which can stand alone if necessary. This approach offers earlier occupancy, and realization of the dream.

We have all seen how in the past decade or more, the Russians have had a working space station with phased growth, while us haughty Americans have insisted on leapfrogging in one mighty leap from the “Model T” Skylab to the “Taurus” S.S. Freedom. We are the ones who have lost both time and experience in going for the idyllic all at once. If we want space oases sooner rather than later, we need a humbler approach. Insistence on unitary monostructures, because they look so damn nice, will end up pushing off their realization a generation or more, if not altogether. We have canoes, we want aircraft carriers. So we don’t build anything until we can build the latter. A certain prescription for self-paralysis!

But, but! Okay, you can build a barbell structure that can grow modularly into a torus, and you can build a longer cylinder as a series of sausage links, but you can’t build a modular sphere! Perhaps not. But mind where we are in this discussion. If we accept a lower gravity standard, and thus a

smaller radius. We can build a series of smaller spheres, one by one, all along the same axis, expanding auxiliary systems and elements as we go along. Similarly, we could build smaller complete torus rings one next to the other, again along the same axis, and again expanding auxiliary systems as we go along. All growable designs converge on the asymptote of the cylinder whose radius is set by rpm and design gravity level, and whose length is codetermined by demand vs. engineering practicality and structural stability.



The key that unlocks the door to modularity then, seems to be the giant step of admitting, ‘yes, while branding everyone else as “planetary chauvinists”, we’ve been repressing the more serious terrestrial chauvinism of the 1G standard, in the interests of avoiding the risks and challenges of adaptation to environments with strange frightening parameters’. Do we want the space oasis dream bad enough to compromise, or not? Will we continue to speak with a forked tongue, rejecting limits to growth, but capitulating to limits to adaptability? It doesn’t matter really. Those who won’t agree to adapt will just not be part of the future. *What needs to happen, will happen.*

The missing “rest-of-the-world-not-seen”

The second red flag is the notion, implicit in unitary mono-megastructures, that these are “worlds” unto themselves. The concept of world is a complex one, but one of the quint-essential elements of that concept is that it is an integral flow of horizons, *not all of which can be seen at once*. Only the torus satisfies that central significance. Yet, if “world” is a linked set of “valleys”, a torus still falls short. It is still a mono-vale, a valley that has itself by the tail.

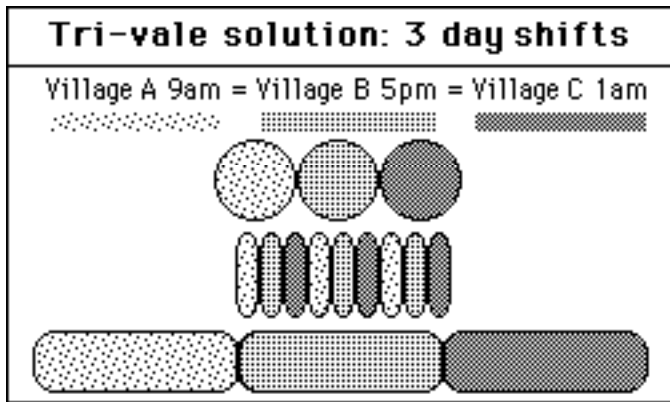
Forget the crack cocaine appeal of those picture postcard views: “a moment being awestruck, a lifetime being suffocated” — because “that’s all there is”. The high of First Glimpse is pitifully inadequate to the task of buoying day-to-day morale. In the long haul, the need for *the-rest-of-the-world-not-seen* is absolutely crucial to sanity.

Polymeric Modularity, Divisible by Three (3)

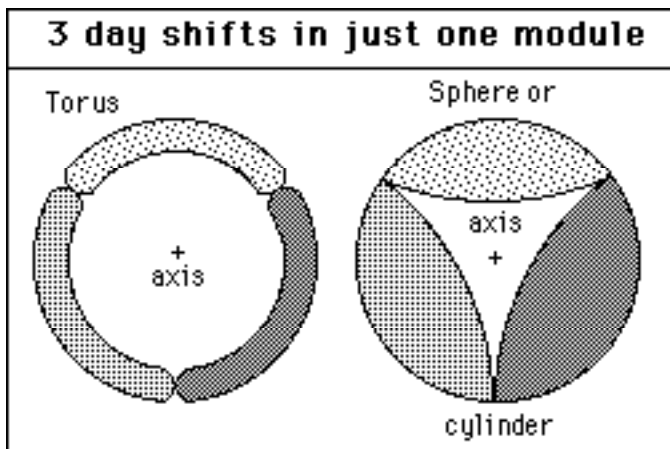
Yet another unaddressed chauvinism *incarnate in all the classical space oases designs* — and not so coincidentally endemic to populations of professors and students as well as white collar movers and shakers in general — is what we might call the “uni-shift day job ideal”. The need to get our money’s worth out of capital equipment etc. by having such stuff operated and run around the clock is something we can take care of by relegating such duty to types lower down the totem

pole who can be consigned such god-awful duties as working “second” and “third” shift.

On Earth, frankly, there *is* no choice. The Sun rises and sets but once a day. Space oases people, who are proud of the fact that they can engineer more ideal environments, have failed to pick up on the fact that the above fact too can be “remedied” in free space. Build a triple module, *tri-vale* structure (three linked spheres, three torus sections side by side, a three-sausage-link cylinder) and engineer the solar access to each *so that there are three staggered sunrises and sunsets* and you create in effect a **three village town**, in which the residents of each have day jobs, everyone gets to go to work in their morning, come home in their afternoon. Yet not only does all capital equipment get operated around the clock but all public facilities from offices, to schools, to entertainment facilities and parks get used 24 hours a day. If a light assembly facility is located in village A, then, at the afternoon shift change replacement workers from Village B (where it is local morning) come in. And at 11 pm, workers from Village C come in (where it’s morning there). The elegant *final* solution.

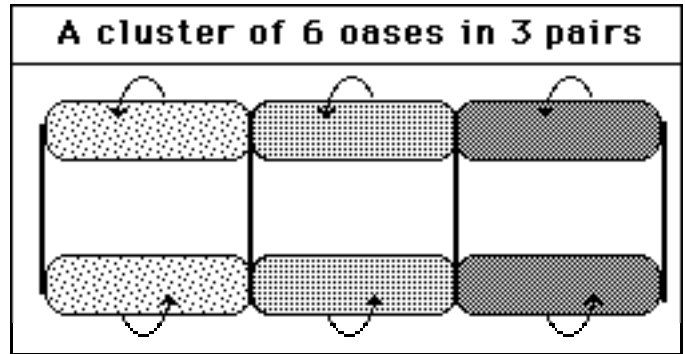


This 3 shift solution is available on a smaller scale - if growth beyond the initial sphere, torus, or cylinder module is seen as a distant or uncertain possibility. A single torus module can be triple-pinched to form a three-link ring with a different lighting schedule in each link. For the single sphere or cylinder a triple concave opaque sky “firmament” will accomplish the same sequestered lighting regimen.



On the other end of the expected growth range, if boom prospects warrant, a larger scale option would be a physical clustering of six oases, i.e. three staggered shift

torque-balanced counter rotating cable-linked pairs of spheres, toruses, or cylinders. The torque neutral physical link can be as simple as a cable or as complex as a cableway or transport conduit (at zero-G, of course, since not rotating). A single such pairing, already foreseen by O’Neill, could only provide a two shift system. But admittedly, that is already an enormous improvement. But why pull the punch, when you can go all the way with this idea? More about space oasis clusters below.



Nothing, of course, prevents the eventual construction of more ambitious larger girth habitats, whether of lower rpm, higher gravity or both. But we have to live, work, and build our way through the 21st century before we can realize 22nd century dreams.

A Forgotten Design Option — the Helix

The ideal compromise between a modular tri-vale complex that is too small in toto, and one that is too large even in phase one (the first module or ‘shift valley’) is offered by a design option the classic designers totally overlooked. According to ivory tower geometricians, there are only three possible generic space habitat architectures: the barbell/torus (i.e. the torus is a fully rotated barbell), the cylinder, and the sphere are the only possible three dimensional balanced forms allowed by rotation of the appropriate subset of Cassini curves. Balderdash! That ignores rotation *combined with motion along the axis*. Do that with a sphere and you get a cylinder, with a torus you get a double walled dewar cylinder, with a cylinder you get a longer cylinder. But far more interestingly, do that with a barbell, and you get a double helix, a trick learned by nature eons ago and without which none of us would be here. So much for the ivory tower guys.

Further, a *three*-armed barbell with three equally distanced pods is just as rotationally stable as the simple two headed one. Rotate that and move along the axis at the same time and you get a triple helix.

So? So this gives us a habitat with three separate daylight-staggerable helical valleys capable of indefinite parallel growth. Start with three small pods — stop where you want with a triple helix habitat of set radius but of indefinite axial length. Such a biodynamic masterplan will yield about as world-like a convoluted transhorizontal linkage as we are likely to be able to devise to fit the constraints of artificial gravity physics. Here we have a world of places other than that which we can see at one time, yet still have sight lines long enough for visual relief, *plus* room for growth. *The kids can stay.*

[see MMM # 12 FEB ‘88 “Space Oases: Part 4. Static Design Traps; Part 5: A Biodynamic Masterplan” - republished in MMM Classics #2]

That each Space Oasis habitat will be an insular nation unto itself is unlikely

Many a person strongly drawn to the space oasis dream admits to being more attracted by the vision of innumerable politically independent entities and the libertarian opportunities that would seem to portend than by the idea of living in space itself. Alas, history does not support the belief that the mere multiplication of small national entities results in an explosion of freedom. Indeed, if the O'Neillian designs are followed without modification the very real limits to growth that will all too quickly be felt within each habitat will make necessary severely draconian limits to individual freedoms, especially those of procreation, consumption, and life style.

Small nation states are in general (exceptions like Singapore only proving the rule) more vulnerable to economic and hence political instability than are larger ones. Small nations are the more likely to be founded on ethnic, religious, or other arbitrary and artificial grounds; larger nations the more likely to be pluralistic and open-cultured.

If there is a way to politically and economically cluster individual space oasis habitats in associations that work, these will be the more stable, and in the long term the more prosperous. Isolation favors only those things that cannot compete in the open, usually for good reason. But there *will be* island states in space. For one thing, not every location that favors a space oasis will favor more than one. Fine. Those who want smallness, isolation, and parochialness shall have it. Of rural space oasis towns there will be some.

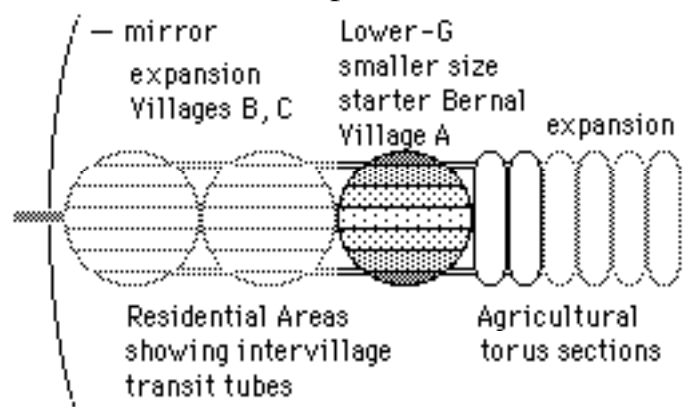
By the same token there will be locations prime for major economic activity, like Earth-Moon L4 and L5 and Earth-Sun L4 and L5, where space oases may multiply and cluster. Especially in the former closer quarters, there will be some very real danger of collisions from mutual drift, probably on a frequency far greater than that of near Earth asteroids striking the home planet. That and other benefits may predispose the builders of such oases to work in collaboration towards physically clustering these habitats.

Habitats can be clustered in torque-neutralizing pairs attached to a common non-rotating structure composed of solar power grids, heat radiators, storage warehouses, joint-endavor manufacturing and micro-G factories and labs, micro-G hotels, micro-G farms (if they prove to have an advantage for some crops), water treatment and waste recycling, inter oasis mass transport, passenger and freight spaceports, and more.

The resulting metropolitan complex should be much more vigorous and dynamic and satisfying a place to live, and more politically stable. The joint population could be fairly substantial. By transcending the limits of the isolated size-fixed unit, the limits to growth will be further put off.

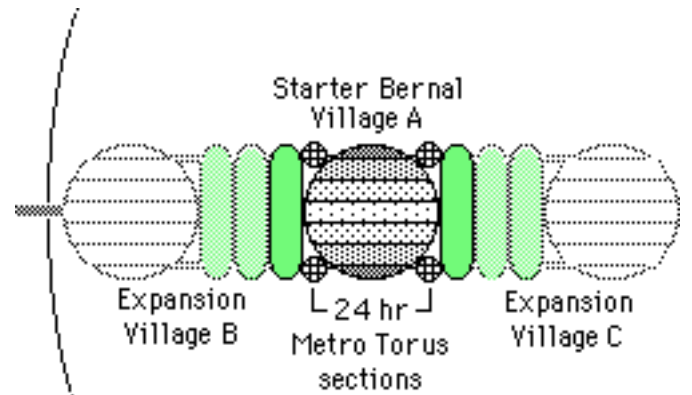
The Lagrange point prime real estate locations entail a physical "commons" that can either be treated as a lawless "no mans' land" or as the subject of agreed upon privileges and responsibilities. Even space oases that are not physically linked with others may, sensing real common interest, seek political alliance and association. [See MMM # 57 JUL '92, pp. 5-7 "META-XITY: Residual Problems of Classical Space Settlement Designs and Synthesis via Polymerization on the 'Metazoan' Plan" - Republished in MMM Classics #6]

I. The Bernal Sphere Reinvented



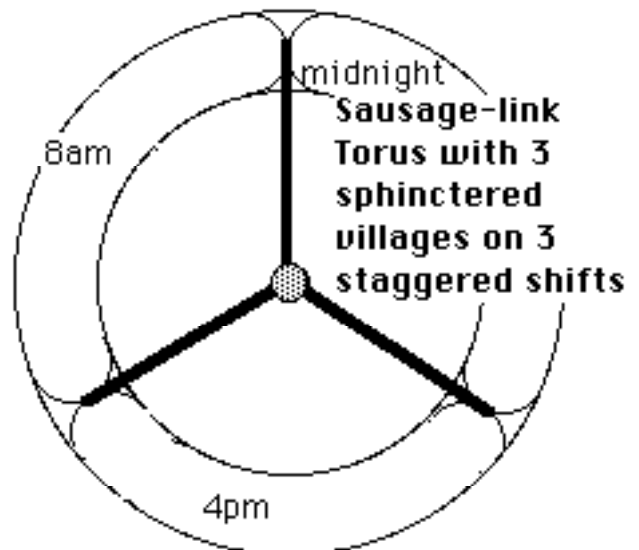
One method of expansion: Mirror works full time, lighting two villages at a time; each getting sunlight 16 hrs (2/3rds day) a day on schedules staggered 8 hours apart. Transit tubes are placed 60° or 120° apart and act to stiffen the complex.

An alternative expansion design



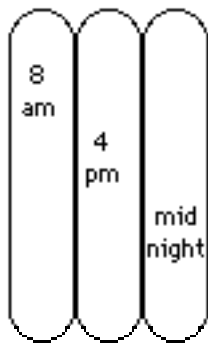
II. The Stanford Torus Reinvented

Single Torus Concept



Dayshift chauvinism, an unexamined presumption common to academics and business people alike, is one serious flaw of the classical O'Neill Space Colony designs. These facilities *must* be in operation around the clock, "24/7" to have a chance to make it economically.

Multiple or Banded Torus Concept

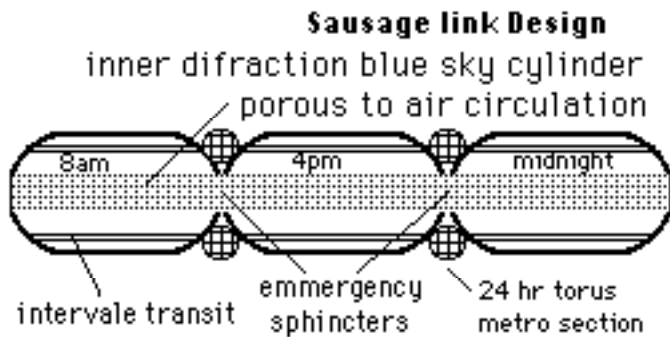


Alternate Scheme for larger colony - 3 torus rings on staggered shifts

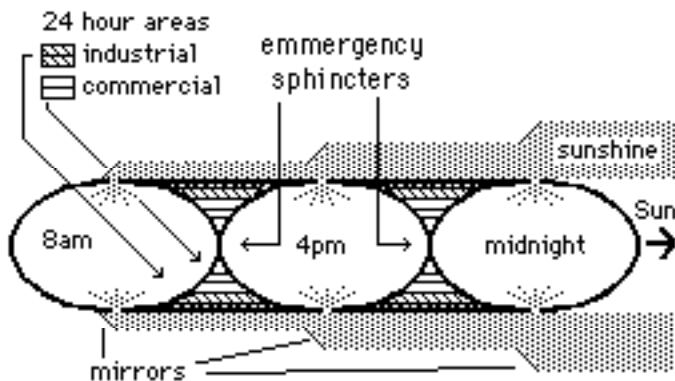
III. O'Neill Sunflower Reinvented

Below are two ideas for generally cylindrical habitats that can be constructed in individually viable sections, yet function as an integral whole on completion. No attempt has been made to engineer every detail, the idea being simply to suggest some options that might be pursued further.

Tri-vaile O'Neill Cylinder



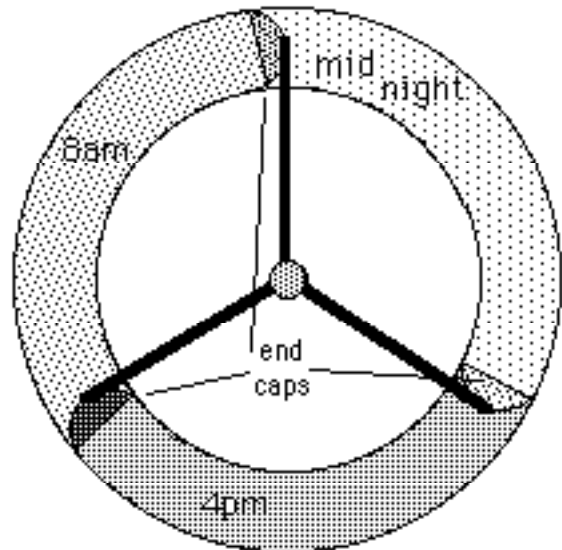
Another Design 3 sphincterable ovoids with common outer cylinder wall



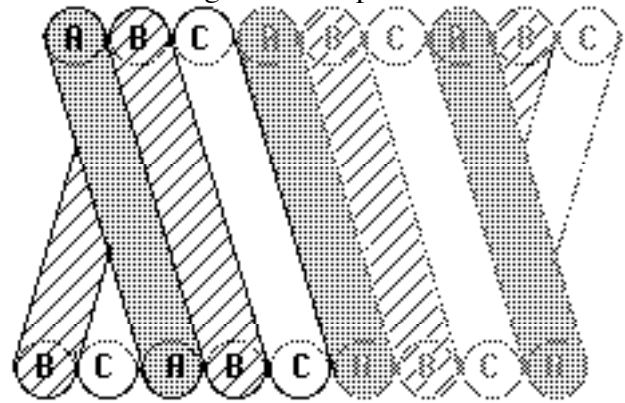
[inspired by a drawing sent in by Jeff Sanburg of Skokie, IL]

In the event of catastrophic decompression of any one ovoid, the other two ovoids would remain intact, as would the industrial area between two intact ovoids. The industrial areas are more vulnerable in this design than the Metro toruses in the design above. Both designs above could use similar sunshine delivery systems.

IV. Triple Helix viewed end on from end cap start of three growing villages with shift-staggered day-night cycles



Triple Helix — Side View Three Villages with Expansion Potential



Biggest Challenge for Helix designers: engineering solar access either with axis pointed at the Sun or perpendicular to the Sun.

“works-in-progress” — input welcome!

This has been more an exercise in redefining what a space oasis should be: (a) looking to minimize construction expense and lowering the threshold to initial realization by removing dogmatic insistence on a chauvinistic 1-G standard; (b) through modularity providing greater safety, the opportunity for growth, and more world-like inner horizons, with the bonus of an elegant solution to the three shift problem.

The designing activity has been kept to the minimum needed to illustrate how these new standards and criteria might be effected. There will be plenty of time before we are ready to build a new revised Island One in which to reengineer all the systems and subsystems needed to make each design work.

Your input in moving these discussions further along is very welcome. So is new artwork. In time the classical designs will be seen as brilliant but simplistic exercises in visioning that served their purpose: showing us that *man can live in free space*, not just on natural worlds.

[Pioneering a Moon-appropriate art medium]

WATERGLAZING

R&D Report: #3 — 6/4/'95

by Peter Kokh, pioneer investigator

At last report [#2 10/14/'94 in MMM # 80 OCT '94 p. 11 - republished in MMM Classics #8], two paintings on 8"x10" glass panes and one on 6"x6" unglazed tile had been exhibited at the Midwest Space Development Conference in Cleveland. The Palette, designated # 102, contained black, white, pale yellow, rust, and green with mixed shades of gray, pink, orange, and yellow-green. There remained several more inorganic regolith-derivable metal oxide and salt pigment powders yet untried. Our first priority was to find a blue. *"If I can't do blue, I'm not going!"* I told everyone. It's my favorite color.

We have blue!

The initial research had already extended me beyond my available discretionary income and I let the project sit for some time. Finally, this past April, with the International Space Development Conference (also in Cleveland) less than a month away, I bit the bullet and took the plunge, plunking down some \$120 for a paltry 25 grams (less than an ounce!) of Cobaltous Aluminate, known commonly as Cobalt Blue. I had good reason to expect the investment to turn out to be misspent money. Two other salts I had tried, nickel sulfate (turquoise), and potassium chromate (bright yellow), had not worked, reacting on contact with the sodium silicate and coagulating into unworkable hot globs. But risk acceptance is part of experimental research. It had to be tried.

It worked and worked fine. What a glorious pure rich blue! Fortunately, too, it was dark enough that I could cut the cost substantially by mixing it with titanium dioxide white to produce medium and pastel shades. With this sole addition, we did four new pieces for the ISDC with this new palette 103.

"Reclamation Dream" is an "as is" Moonscape in blacks whites and gray tones painted on the reverse side of a glass pane. A spherical area in the middle of the frame is overpainted on the front side with sky blue reclaiming black space, green and flower-studded meadow reclaiming gray slopes of regolith, a blue lake reclaiming a crater.

To further show the versatility of this new settler-appropriate art form, I painted a terra cotta flower pot in rusts greens and whites, and an aluminum bowl in whites, greens, blues, and rusty pinks. Plus a decorated mirror. In the hopes of raising money to purchase additional candidate powders, each piece sported a sale price at Cleveland, save the original work which remains "NFS", of course. Chuck Schlemm of Middle Tennessee Space Society purchased the earlier tile piece, "Heinlein Roses". Many passed by the exhibit without pause, but others were alert enough to realize that here was something worth looking at, even if the artistic quality was questionable.

The one sale was encouraging. Add in a \$50 donation from *Doug Armstrong* of Milwaukee, and we were enabled to place a \$150 order for iron sulfite (fool's gold) and vanadium pentoxide. Hopefully, these will work and expand the palette.

"Regolith Impressionism"

The "paints" have to be mixed on the spot in small amounts as being adhesive- rather than solvent-based, they set up quickly. For doing small pieces, this is actually an advantage as you can paint an adjoining section in another hue almost immediately. But barring a major surprise from a future unplanned line of experiment, we don't see these waterglass paints ever being sold premixed by the gallon and able to be poured out in a tray and applied by roller to do whole walls, for example. This medium seems to lend itself to art work primarily, and we should be thankful enough for that.

The same characteristics make fine detail "high resolution" work almost impossible — although more skilled artists may succeed where I have not — one reason we so badly want to involve others, hopefully with more practiced talent. But it would seem clear that the lower resolution detail that is achievable with these paint preparations lends itself ideally to an art style which has already achieved a high state of achievement, and acclaim: impressionism. We'll continue to labor in this direction accordingly, without wanting to exclude attempts by others to go beyond.

The works executed last fall, were all done with traditional bristle brushes, hardly an authentic lunar tool!. But the priority had been to demonstrate the paint itself, not the applicators. This spring, however, three of the pieces were done with two new lunar-appropriate applicators in addition to primary reliance on the brush. Not to keep you in suspense - we tried "sponging" techniques using wads of fiberglass insulation and steel wool. Both worked, allowing a kind of spotted detail we could not achieve by brush. Experimentation along this line will continue.

"Aging" of Waterglass Works

This winter a certain blotchiness had set in the original two pieces done on the reverse side of glass, slowly spreading. This was alarming. Was the paint delaminating from the glass? Was it crystallizing? Had I painted too soon after cleaning the glass with Windex? Was the very dry warm winter air in my unhumidified northern home at fault? I tried two things with the Spring batch that may confirm or rule out a couple of these guesses. But by now, the suspicion is that the process is not fatal, and some who have seen the early works recently think that it adds character and "relief" to the painting. At any rate, this is an experiment, and unexpected results are what research is all about.

[Readers can learn more about Waterglazing Painting with the latest updates online at:

http://www.lunar-reclamation.org/art/painting_exp.htm

This effort is currently on the back burner, as we have not found a workaround or countermeasure for the "aging" problem cited just above.

The experimenter, Peter Kokh, can be contacted at kokhmmm@aol.com or 414-342-0705.

Vision without action is just a dream

Action without vision is just activity

Vision and Action together can change the world.



Some of us will need a place to let our hair down before we can call a new world home

by Peter Kokh

Bars and taverns have always been prominent in science fiction, providing the setting for rendezvous, intrigue, trade and smuggling deals, shanghaiing hapless unwilling ship hands, or just providing comic relief. Many of those in media science fiction have become classic: the cantina on Tatooine where young Luke Skywalker and Obi Wan Kenobi gained the services of Han Solo, Chewbacca, and the Millennium Falcon. Ten Forward on the Enterprise D. Quark's on Deep Space 9.

Yes, bars are also places where alcohol is abused, drug deals made, partners picked up for one night stands, prostitutes engaged, and drunk drivers set loose etc. But the shady side of the bar scene can never discredit the legitimate and useful relief valve functions such places serve. Those uncomfortable with the subject because of tragic family situations need not read on.

The bar for many serves a useful function, on an occasional if not a regular basis. It is a "neutral" scene removed from the stresses of workplace and home. When not abused, alcohol *is* a tension and stress reliever, and often just as importantly, an inhibition and shyness relaxer. The watering hole is a place where one can go "to talk it out", "get things off the chest". Here one can hope to be listened to, however noncommittally. Here one can tell and trade stories, make plans and launch joint endeavors, think bold and uninhibited thoughts. Here one can socialize, mix, make new acquaintances beyond the small circle provided by the workplace or neighborhood.

One comes here to dance perhaps, or at least to flirt or be titillated by a flirtation; to see and be seen. One can find others with which to share a game of dice, of darts, of pool, maybe even of chess. A lunar bar might boast a wide stock of imported games, electronic, and classical, that most settlers might not be able to afford for themselves. And juke boxes!

Besides coin-metered canned music, where else can one go and listen to live music, enjoying entertainment, skits, comedy, song, even staged bar room brawls — for free or for a modest cover charge? Here to settlers and those on assignment can come to dance, enjoying the freedom of one-sixth gravity.

Here amateurs and others can try their hand (or mouth) at expensive establishment-owned terrestrial musical instruments such as the harmonica, flute, guitar, piano, synthesizer. But many securing a gig at the local pub will bring their own home grown lunar musical instruments: steel (pan) drums made from steel shipping barrel ends, bells, cymbals, "saws". xylophones and marimbas - none of them using wood, copper, or brass which would have to be expensively withdrawn from the settlement biosphere or imported. [read "Moon Music" MMM #3 MAR '87 - republished in MMM Classics #6]

The Lunar tavern will be a place where one can come to watch special (sports) telecasts from Earth in the company of other rabid fans. On the other end, bar-sponsored teams could play a major role in the development, refinement, and popularization of uniquely lunar team sports, just as some bars nourish local talent in song, dance, music, comedy and acting.

The first bars beyond Low Earth Orbit will be on board on cruise excursion ships looping the Moon and Earth-Moon Ferries. Once an outpost is established, the first bar on the Moon will be little more than a small liquor cabinet in the ward room. But ultimately real private establishments open to public will appear as the population on the Moon mounts to the point where such enterprise is worth a try.

What will a lunar bar do for atmosphere (not that many terrestrial bars give it more than a passing thought!)? Lunar bar decor will not, save as the exception that proves the rule, sport rich woodwork or paneling, wooden floors, bar tops, tables, stools etc. Nor will plastics and other synthetics be much in evidence. Economics will make lunar-processed materials the standby: iron and steel, aluminum, cast basalt and ceramic, glass, stained glass, glax (fiberglass-glass matrix composite), concrete and lunacrete, etc. Working with this suite of materials will provide ample and rewarding challenges for lunar interior architects and designers.

The decor of most bars is just thrown together, of course, and there is no reason to expect a higher score for lunar tavernkeepers. But somehow I think that at least the first few will have enough sense of history to try to make their places of business truly distinctive and at the same time pioneer rather than follow decorating trends with the new materials. To organize the setting, there may be a focal point provided by some memento or heirloom from back on old Earth, perhaps even supplying the place with its name: a brass spittoon; a large stein; a shark jaw; a stuffed moose head; a nice quilt; the empty shell of a vintage juke box; a ship porthole — the possibilities are endless.

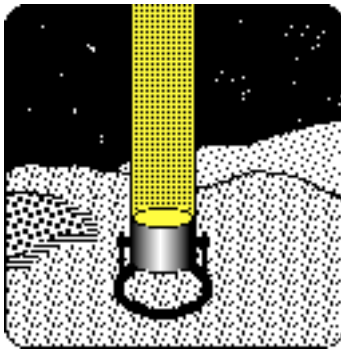
Or a lunar tavern might have on display an interesting item salvaged from an abandoned or crash-landed spacecraft or settler ferry. Or some other piece of surplus frontier museum-ware like a zero-G johnny.

Not all bars will take their names from such prized possessions. There will be simply Ted's Place, and Cal & Sally's. Other taverns will be named after local geographical features (Crater Rim Bar) or allusions to the dayspan/nightspace cycle (The Long Dawn), shielding (Six Feet Under Bar), or typical lunar occupations (Prospector Pete's, The Dusty Boot). Of course, some bar names may make allusion to missed aspects of the terrestrial experience or to spacefaring lore.

Bars in principal lunar (space) port cities will have a different flavor than those at scenic concessions or at sleepy backwater outposts. [read "Harbor & Town" in MMM # 56 JUN '92 pp. 3-4 - republished in MMM Classics #6].

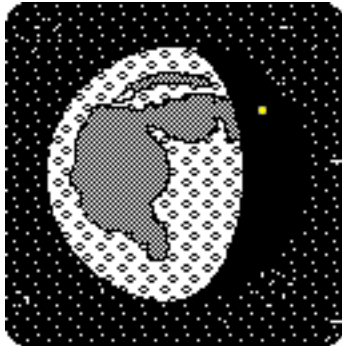
What to drink? Well that's the subject of another article. You might not find your favorite brand or brew but imports or no, people have always found a way to provide! Like schools and churches and other familiar institutions, the tavern too will survive lunar transplantation. EOM

The Glint in the Moon's Eye

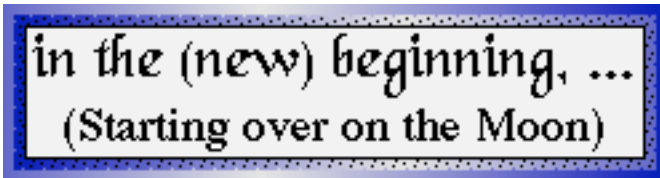


One way to get across to people world wide, whether they be educated TV watchers or not, that there is something new going on on the Moon, would be to place a large beacon, pointed Earthward, near the launch pad of the beachhead Moon base (L). It would shine only during nightspan, being clearly visible

in the unlit portion of the Moon's nearside (R). What color would show up best? Red? Green might be less alarming, signifying plants as well as humans. Should there be messages flashed by Morse code? How many lumens, watts? For more on Starting Over on the Moon ⇒ below.



[Beginning a New MMM Series]



I. Bursting Apollo's "Envelope"

by Peter Kokh

Apollo was without precedent. For scouts of Earth to break free from their womb planet and set foot on what had always been an unreachable celestial sphere was a clean break with all that had gone before. It electrified civilization for a moment. Yet for all these nine manned missions to the Moon accomplished, six of them landing, *so many really basic things were left undone* that roundly shattering that precedent will be easy. We mean no disrespect! But, yes, easy.

⇒ Twelve men set foot on the Moon. Yet none of them slept in a bed there. The LEMs had only hammock-slings. All twelve walked in one sixth gravity, but only with cumbersome

pack-laden pressure suits - the pressurized LEM "cage" was scarcely big enough to pace back and forth in place. So no one experienced what it is like to walk in lunar gravity, not really.

⇒ All the missions were [lunar] morning ones. No one experienced a lunar sunset, a lunar night, a lunar dawn. We never even hung around into local afternoon.

⇒ We ate and slept in our station wagon, not even pitching a tent. In effect we just picnicked there. Since our vehicle was our shelter, we took it with us when we left, and there is no camp, no cottage, to which we might return. We never visited any site more than once. We left no "building" on the Moon, not bringing any with us, not erecting any.

⇒ We never stayed long enough to plant, or grow, much less to harvest. Even the science we did was just field work collection stuff. We brought along no lab. Nor did we play much. Sure we romped around in our suits, hit a golf ball, and playfully rigged our flags so they looked like they were flapping in some vacuous breeze. Playful, yes. Play, no.

⇒ We were there, that's all. Like Kilroy. And then we were gone, and are gone still. We took samples from which to learn *what the Moon is made of*, but which have since been guarded so jealously by an intermediating *priestly* class "lest we never return" that we have not been free to learn from these samples *what we might make out of what the Moon is made of*, as if to guarantee that we would never find the confidence to return on a live-off-the-land basis.

⇒ We left stuff too -more than footprints, stuff that could someday be prized pioneer relics in local lunar museums. But to date, more than two decades later, these leavings only remind us of our failure to build upon what we had done, to stand tall on the shoulders of our heroes. The "revolution in history" has been downgraded to an anomaly, a distraction.

A new beginning

So much of both the technology and the expertise that carried the Apollo program on to its brilliant successes has been lost, dismantled, even deliberately destroyed, that we can no longer just repeat these humble sorties. They cannot even be called beginnings since they have been robbed of the chance to lead to something more that follows.

Not quite. *We have the knowledge*, the record, and some teasing results of matter-starved experiments that suggest what we might be able to do with lunar regolith - make oxygen, iron and steel, aluminum and titanium, cast basalt and ceramic objects, sinter blocks and concrete, glass and glass composites - in effect fuel, air, water, tankage, vehicle and habitat parts, furniture and furnishings. We could even do out-of-fashion soil-based farming. Bring back with us but talented people, tools, and seeds, and we might just make a go of it.

With the total absence of political will, any return will have to be humble, laying down a few foundation stones at a time. Our first beachhead can only become permanent in time. But even if the first crew returns home for some while before the next is sent, it will have been easy to shatter *all* Apollo's achievements with the first mission.

(1) We leave a habitat structure on the Moon, perhaps returning to an awaiting orbiting ferry (serving a function like Apollo's command modules) ascending on a *cabinless* platform (not

unlike the Apollo rover) protected just by space suits.

(2) Our habitat has room enough to walk around, and to sleep horizontally in cots or on air mattresses, and is big enough to boast both private and common room areas.

(3) We “dig in” our shelter, placing it under a soil-shielded canopy or heaping soil directly upon it to make longer stays possible without high accumulative radiation exposure. Now we have a camp, a cabin, a cottage on the Moon, a permanent structure to come back to, and from which to expand in due course, as we learn to do so step by step, using primarily building materials made on location.

(4) We leave an electronic beacon so that follow on missions can make instrumented landings at the same spot.

Then What?

(5) We stay not only all “day” but past sunset, outlast the long two week night, and start a new lunar “day” before going home. This will be quite a feat, not unlike the first “overwintering” on Antarctica. Even with a nuke source for energy, we’ll have less power than during the dayspan when we can tap sunlight as well. We’ll have to switch from energy-intensive tasks during dayspan to manpower-intensive energy-light tasks during nightspan, establishing a lunar rhythm that may forever after give life on the Moon much of its characteristic flavor. In the process, we’ll have to have in place an advanced, possibly bio-assisted, life support system regenerating our air and water supplies. We’ll also have had to have demonstrated, probably in an unmanned dry run, thermal stability of the station through the nightspan. Shielding will help here too, minimizing exposure to the heat sink of space.

(6) If we stay six weeks or more, we can plant some salad stuffs and bring them to harvest. The first feat for lunar farming and agriculture to come.

(7) We might try some brief sorties outside the station during nightspan. That means headlights, that means lubricants that can take the cold - or magnetic bearings. That means heated spacesuits or an infrared radiating cage or a minimal cabin.

(8) We bring along pilot oxygen production equipment, demonstration iron fine and gas scavenging equipment, a solar furnace to experiment with cast basalt, ceramics firings, iron sintering, and glass production. We have brought along some basic tools for fabricating sample test objects.

(9) There is a parallel Earthside “Moon station” in which problems on the Moon can be addressed in close simulation, and in which terrestrial brainstormers can proactively outline suggested new experimental exploits for the lunar crew.

Exploring Metaphors

Settlement is a long way down the road. But since we are determined to make that journey, we have to humbly begin with some lowly first steps. What lies between our previous “science picnic” visits and “settlement”? Here are some more relevant “meanings” my dictionary offers for some of the words we’ve been bandying about. Running through them might help clarify our thoughts about what comes first.

base: (1) a bottom support on which a thing stands or rests;
(6) *the point of attachment*; (7) a starting point or *point of*

departure; (9) a *supply* installation that *supports* operations

camp: a place where a group of persons is lodged in *temporary* shelters.

fort: a fortified, protected place [here, living quarters and operations center, in a *physically* hostile environment, shielded against radiation, vacuum, and thermal extremes.]

habitat: (3) a special contained environment for living in over an extended period in a life-hostile setting.

hostel: an inexpensive, spartanly equipped lodging offering minimal shelter for short-stay travelers.

outpost: a station established *at a distance* from the main body; a post or settlement *in a foreign environment*.

station: (6) a place *equipped for some particular kind of* work, service, research, or *activity*, usually semipermanent

While all of these terms are applicable as far as they go, none of them are especially *instructive*. And most of them are static, not suggestive of leading anywhere, *thus requiring separate justification of any further steps*, and thus likely to become self-limiting. We suggest that we space advocates who really want to see human outsettlement wean ourselves of such terms as Moonbase, Lunar Outpost, etc. and *look for more pregnant terms that suggest a sequence of phases that lead to something much more*. If we find better terms we must popularize them and thus *alter the culture* in which space futures are discussed. **Words are not neutral.** We must pay attention to their downside or self-limiting connotations. We are in a battle for the soul of humanity. We have to stop using the weapons the enemy gives us and forge our own.

Let us suggest some other terms whose applicability might seem a little forced at first thought, but which we think you’ll agree are rather appropriate:

beachhead: the area that is the *first* objective of a party *landing on an alien shore*, which once *secured and established*, can serve as a base of expansion of the occupation.

incubator: an artificial environment that enables fragile beginnings to become hardy enough to thrive outside.

interface: a common boundary [between two worlds i.e. the life coddling Earth, and the barren and sterile Moon]; (4) something that *enables* separate and sometimes *incompatible* elements to *communicate*.

“Interface Beachhead” & “Settlement Incubator”

If our gambit strategy is to establish a habitat station which serves as an effective interface with the Moon and its realities, then we suggest that the menu of Apollo-besting items given above lists steps in the right direction. We need to learn how to exist on the Moon, on *its* terms, through *its* cycles, boosting our resources *with those it offers*. A successful first Interface Beachhead will allow us to carry on a whole range of human activities in a way that comes to terms with lunar vacuum, lunar sixthweight, lunar day/night cycles, lunar temperature swings, and the absence of organic materials in the lunar soil. More challenging, we must interface with the Moon and learn to do so flexibly, through the handicap of a micro-biospheric barrier as “bubble” creatures.

We have to begin mastering how to thrive on stuffs and materials we can process from the lunar endowment. That

means our interface station/camp/outpost/base/beachhead must have expanding dedicated space for processing and fabrication experiments, demonstrations, and production operations. That means we have to put together talent, materials, and opportunities for at least part time artists and craftsman to learn how to express themselves in the lunar idiom. Call it survival, call it living off the land, call it acculturation, call it dealienization, call it adaptation, call it adoption, call it “*settling in*”.

We can't have wholesale rotation of crews. *Even if* everyone still goes home after a while, those with hard won on site experience have to teach the newcomers before they can turn things over. *Our presence needs to be more than serial.* There has to be an effective “cultural memory” giving enduring “soul” to our individual comings and goings. Given that, the outpost/base/camp/station/interface beachhead will take on a “permanent” life of its own, even though the day that “reupping” indefinitely, i.e. staying for the duration of one's natural life, may be a good ways down the trail.

“Permanent” can apply to the physical structure. That is easy - and “cheap” in a fully pejorative sense. At the other extreme of application, it can also apply individually to people who come to live out their remaining natural lives with no real thought of ever returning to the “old” planet - “forsakers”.

In between is the “permanence” of a growing acculturation between human and Gaian on the one hand, and lunar on the other. While we never want to lose sight of the longer term goal, we need to reject rusting on the laurels of achieving permanence in the first naked sense. All that would achieve is the establishment of an eventual ruin or ghost camp. **FMFM**

II. Going Back with Entertainment \$\$



Profits from accessing space-based energy and lunar resources are far off. Can feeding the entertainment appetite provide a big enough, early enough return-on-investment [ROI] to economically “terrace” an initial manned return to the Moon and a starter base?

by Peter Kokh

That's the idea of the Lunar Resources Company of Houston Texas, and CEO Greg Bennett. Bennett wants to see us return to the Moon, “the sooner the better”, to develop the resources there and establish a two-world economy. Yet turning the first buck of profit from such a venture seems to everyone who has looked at the problem, a long ways down the road. So how do we attract investment capital? That comes down to asking, how can we provide an *earlier* return on investment?

Others have suggested “terracing” our way back to the Moon. LunaCorp's project to put a pair of videocam-equipped rovers on the Moon near the Apollo 11 site and have them take lots of footage on a 6-week-long long overland trek to the Apollo 17 site, could be the first terrace. Film footage would be available to virtual reality players, *for a fee*, at theme parks.

Entertainment ventures are financed by the expectation of fairly quick profits, not from industrialists and manufacturers, but from couch potatoes, the very people who are often most maligned as standing in the way of the future. It would be ironic, and fitting, if catering to their needs provided the missing interim financing link to get things going, again. Leisure dollars are certainly attractive, not being directly subject to national budget deficits or grandstanding politicians with 2-, 4-, and 6- year strains of myopia.

VR, virtual reality, is a new market, one already much bigger than the last over-hyped electronic wonder, holograms and holovision. Will expectations be realized? Will enough people find the VR experience satisfying enough to pay for it? - *on a repeat basis*? This remains to be seen.

The feature film industry, on the other hand, is long and well established. Moviemakers have been quick to follow where the scouts of humanity have led. They have taken us beneath the waves and up/down to the poles. Amateur filming in space began early and we had short TV “shows” done by Moonbound crews. IMAX-made documentaries with extensive footage made from the Shuttle's payload bay, have shown millions the wonders visible from this Olympian perch. And now, “*Apollo 13*”, a real feature film, professionally produced and directed, has been released, much of it shot in *real* zero-G, courtesy of endless short takes on the KC-135 “Vomit Comet” flying one parabolic trajectory after another.

Movie budgets these days are quite large, often in the hundreds of millions of dollars. The first billion dollar picture may well be produced sometime in the next decade. Not all of that investment goes for expensive, exotic sets and blow-your-mind special effects. But enough of the extra bucks are aimed in that direction to lead us to raise the question. Where will movie making take us next? When will “filmed on location” mean “filmed in orbit” or on a loop-the-Moon flight? Not with just tag along cameras manned by specially trained astronauts, but with actual studio film crews and real full-time actors?

Lack of reasonably priced access to space is the real hitch. It is one thing for a studio to “rent” an actually orbiting “set” such as a shuttle flight, or the Mir I complex (especially after it becomes surplus when the ISSA, the International Space Station Alpha, becomes operational). But the cost of getting crews and actors up there is currently too high.

Abracadabra “Cheap Access”, and you can picture Universal or Paramount leasing Mir I, even spending a hundred mil or so to re-outfit the decommissioned station, to serve as the set for some orbital industrial espionage thriller, maybe even involving zero-G sporting or athletic events in some future Olympics. They might even pay to add a new module or two (perhaps, with another investor, a mini-hotel wing?), *especially if*, after the film crews are gone, the refurbished complex can be sold or leased to some commercial concern at a price that justifies the additional investment.

Will filmmakers ever take us where NASA has yet dreaded to tread? Why not? Split Mir I into two complexes joined by a winchable tether, and set the pair spinning around their common center of mass. A pair of flywheels, one at each end, could start the process and control the rate and also keep each subcomplex from twisting at the end of the tether. By

carefully choosing the weight ratio and the rpms, the result could give Hollywood one "Moonbase" interior set, complete with one sixth gravity, and a "Mars base" interior set, complete with simulated three eighths gravity.

Would Hollywood ever pay for a real Moonbase made as inexpensively as possible with off-the-shelf hardware (duplicate station modules or Spacehab modules) and launched with existing cheapest available rockets? If not the whole starter base, how about an extra module or two to fit the plot of a film - ward room?, gym?, laboratory?, garage? - or a rover cabin? Perhaps they will prefer to wait for a passenger version of some Delta Clipper type* SSTO vehicle to enter service.

[* Fans of VTHL type alternatives fail to realize that winged landers are *not* going to be able to be refueled in orbit and go on to the Moon, whereas a VTVL tail-lander *could* do so.]

The odds would improve if, the film shooting over and done with, there was another commercial tenant, signed-on-the-dotted-line, to whom the new Moonbase could be turn-keyed. It would almost have to be a joint venture of some sort. But the idea of Hollywood paying half a billion towards the total cost of such a complex, or towards special features or outfitting on it - to fit the needs of the film (especially if attractive to the turn key tenant as well) is hardly absurd.

The couch potato wants to see and experience Mars for himself, not pay good tax money to send a handful of proxies there. But he wants to see it without spending months of round trip travel time or experiencing real risk and danger. Hollywood, traditional films and VR in combination, can give him what he wants. And perhaps that's why the traditional government sponsored space program has faltered. It has sent only proxies, and, in a failure of imagination (granted the technology has not yet matured), not really tried (or even intended) to take the rest of us along as voyeurs if not as voyagers.

While producers, like anyone else in business, want to minimize costs wherever possible, there is a limit to how much they can satisfy the public with fake special effects. There is a point at which faked fractional gravity is not really convincing. The public too, may begin demanding filming "on location" *once they realize that it is affordable*. Even when filming on lunar location becomes feasible, as many scenes as possible will be shot on Earthside sets. Yet the points are made. The public expects more and more realism, and the money to be made from a major successful film is beginning to approach a respectable fraction of what it might take to do an off-the-shelf return, cut the bureaucratic red tape money-eating pork!

Even a "Cheap Access" SSTO vehicle will not open space for the millions - not anytime soon. Combine Cheap Access with high-tech imaging that puts the stay-at-home "on location" and you have a dynamite combination. It is clear that Hollywood and entertainment have to be a major partner of any realistic near-term human return to the Moon, and of any human expedition to Mars. That will be a hard pill to swallow for many professional space-involved people, but if it proves to be the only way, it is a scenario that *will win out*.

The second half of a 1-2 punch - Advertising

Advertising is already a hand-in-hand not-so-silent-anymore partner of Hollywood film production. Advertisers will be a collaborator on any future repioneered space frontier.

They too have real green money to spend, and will spend it where the couch potato can best appreciate it. In a major turn-around, it is the Resource & Energy people who may be following where couch potatoes demand that Hollywood leads.

If couch potato wallet funds justify a major portion of the money needed to float a first lunar return mission, more than that will be needed to keep the "permanent" outpost alive long term. Any such Hollywood-led venture will have to have industry and commercial consultants in tow. The outpost can be designed to support initial or lead-in industrial efforts. The Moon return crew could set up and tend, for a fee, pilot and demonstration oxygen production, iron beneficiation, and other equipment. The base would have to be co-configured so as to meet a turnkey operator's needs. Anything commercial and/or enterprising fits the scenario, and if a healthy mix of money-drawing activities is what it takes, that is what it will be. The only thing that is sure, except to the ostriches amongst us, is that the principal player *will not be* some government agency spending the people's tax money for intangible benefits.

The "terracing" paradigm is still in its infancy. We can only see the sketchy outlines of a for-profit-step "terrace" here and there. We are extrapolating on faith that the profit motive can find a sequence of early **return-on-investment** efforts that will succeed in establishing humanity, and Gaia, securely and permanently beyond the Earth Biosphere's atmospheric confines - the "R.O.I.al" road to space.

Is it so unthinkable that Hollywood could or would grab the lead - and not just tag along "later, when it's safe"? Isn't it just a case of a student or disciple growing up and becoming the teacher? Surely none of the world's space agencies have learned how to push the public's button. Hollywood knows how, or at least may soon be willing to gamble a well-hedged billion or so that it does.


No one is saying that entertainment can do the whole job, or that we can start lunar development with a "Six Flags Over Copernicus" theme park. What Bennett and company are saying is that perhaps, in this era when every other potential player is waiting for the other to take all the gamble and get things started, this is a job i.e. priming the pump, that entertainment and advertising dollars may be up to, and that once established, a Moonbase *with a commercial for-profit culture* will take on a life of its own, quickly attracting multinational conglomerate developers and industrialists and energy people.

The Lunar Resources Company is not intimidated by commonly accepted cost projections inflated as they are by the expectation of continued NASA-business-as-usual rules of the game. **He who takes the plunge resets the rules**. It may well take a player not addicted to government money, but with plenty of experience in tapping the ultimate deep pocket, that of the couch potato.

The Artemis Project™ is LRC's name for its Commercial Moonbase endeavor*. At present Artemis is a trial balloon scenario using existing hardware. As new hardware comes on line, and alternate ways of getting the most out of novel combinations of existing hardware are realized, the continuing brainstorming behind this scenario is sure to advance. It is thus quite unfair to take cheap shots at Artemis on the grounds of its initial scenario.

Other criticism and skepticism centers on the real depth of the entertainment dollar fountain. But here again, since LRC is willing to consider a mix of commercial activities and functions that will not require landing too much weight on the Moon or require too much pressurized volume to support, this criticism misses the whole point.

Space for profit is a path not yet taken, and the size of the population claiming to be from Missouri is sure to swell until success brings out of the closet the “I knew it would work all the time” sudden majority.

But there are still those who do not yet realize that the old world order is gone forever. *Public Space is dead.* 

Prize Lunar Real Estate locations with special attractions *other than mineral wealth*

by Peter Kokh

Impatience carries risks

There are those so impatient to return to the Moon that they disvalue any further robotic missions designed to reveal where the richest and most accessible resources lie as “money sink distractions”. Yet, to reduce the chances of the first human outpost becoming a ghost town in unseemly short order, the careful selection of a site especially capable of supporting viable economic activity is hardly unimportant. Rather it is impatience that needs to be dismissed. Impatience always backfires. That’s a Cosmic Law. There is no point in deliberately blindfolding ourselves and playing “Pin the Tail on the Donkey” with a Moon map as some apparently want to do.

The tasks of a First Outpost

At the same time, it is possible to argue that *any* good site will do to demonstrate the viability of a permanent human presence on the Moon. The task of such a beachhead is *to survive* the dayspans and nightspans, the heat and the cold, the radiation and solar storms and micrometeorite rain, the absence of a biosphere rich in organics and volatiles. Next the aim is to begin demonstrating an ability to use the resources that are *common* on the Moon to provide some continuing support and a respectable part of the wherewithal to expand.

Distribution of Lunar Resources

The Moon’s major resources (oxygen, silicon, iron, aluminum, calcium, titanium, and magnesium) are distributed rather homogeneously (relative to their very uneven redistribution on Earth). So, the argument goes, we can always pick a second more advantageous site to begin industrial settlement in earnest. Indeed, one might argue, the lessons learned in the initial demonstrator outpost might warrant a fresh start elsewhere, rather than expand upon the trial and error dawn base.

While there is certainly merit to this argument, it is also likely that whether those planning and going on to deploy the first base care or not, additional robotic resource-finding missions *are likely to be flown before* the first outpost can be erected. In that case, it would be foolish not to take into consideration the knowledge those probes supply.

The relative advantages of some sites over others calls for careful consideration - “coastal” sites

Some general considerations can be made now. *Both* from a resource using *and* a tourist/film-making point of view, it would be stupid to locate the outpost either in the middle of crater-pocked highland terrain, or in the middle of the much flatter maria terrain — when by picking a “coastal” site the mineral and scenic diversity of both (highland and “sea”) are present. Happily, innumerable sites fit this requirement.

Early Iron Extraction and Production

If early industrial activity beyond oxygen extraction is likely to center on iron as the easiest element to extract and produce, we already have fair evidence of extensive areas that fit the bill. We’d be suicidally foolish to locate elsewhere.

Public Awareness Potential

Another point of convergence is maximizing public interest and awareness. This should be important both to those who would like to see a government Moonbase (in the mold of Antarctica’s McMurdo Sound) and those who would like to see a civilian commercial outpost (like most every for real burg on Earth). One sure way of doing this is to locate the base in an area that can easily be identified by the trained naked eye, or at least in binoculars. Perhaps others in the habit of studying the Moon with the naked eye might not concur, but the feature I find easiest to locate at all phases of the Moon *visible in early to middle night hours* is the Sea of Crises, *Mare Crisium*, to the north east of center. This oval Mare, the size of Wisconsin and Upper Michigan together, is clearly distinct from the “chain of seas” that run into each other: Fertility, Tranquility, Serenity, Rains, the Ocean of Storms, etc. I am aware of no one else who is partial to Crisium. Other proposed locations in Fertility, Tranquility, Serenity, Imbrium, the crater Alphonsus etc. can be picked out by the *trained* eye easily enough in binoculars, but that makes them unidentifiable for the masses. Anyone can learn to spot Crisium immediately. Somewhere along the shore of Mare Crisium, along the highlands separating it from Mare Tranquilitatis or Mare Fecunditatis could make a fair site. Of course, this is only one consideration and must be weighed along with others.

Dayspan naked eye identifiability is not the only PR trick that promises to build public awareness. A nightspan beacon near the outpost, beaming enough lumens Earthward to be clearly picked out, would certainly command much more attention. This would suggest placing the outpost in a part of the Moon that is usually not illuminated when the Moon is above the horizon in early evening hours - in other words, well into the western hemisphere (coastal/shore areas of western Oceanus Procellarum, the Ocean of Storms, or in the Aristarchus area for example). In contrast, a beacon in any of the eastern seas (Tranquility, Fertility, Crisium, etc.) would not be visible until the waning (post full) Moon that rises later in the evening and would be noticed by far fewer people.

Improved vs. Unimproved Sites

On Earth we distinguish between improved and unimproved sites. The later lack electrical and water utility access. But even unimproved sites on Earth have atmosphere and access to at least some rain. No site on the Moon has as much, *every lunar site* being *radically* unimproved.

Shade

Yet some sites have assets, beyond minerals, that other sites do not, such as appreciable part-time (and rarely, full time) shade. This can be important in planning thermal equilibrium maintenance with the placement of heat rejecting radiators etc. Rille walls and crater walls and escarpments all provide part time shade depending on the local path of the Sun across the sky. In general such minimally improved sites are scattered everywhere, but are the more densely located the nearer to the poles where the maximum elevation of the Sun over the equatorward horizon is lower. This would seem to directly compete with the landing/take off economy of equatorial sites. But keep in mind, with the Moon's lethargic rate of rotation, the touted desirability of equatorial sites is *grossly* exaggerated.

“Lee” Vacuum — Lavatubes

More significant an asset than shade is true “lee” vacuum, where there are surfaces never exposed to the lunar sky, and thus always protected from cosmic radiation, solar ultraviolet, solar storms, and the micrometeorite rain as well as wild day-night sunshine-shade temperature swings. Such areas will be ideal for warehousing and garage space and unpressurized industrial operations. They exist *underground*.

The Moon has no limestone caves made by running and dripping water. But it does have lavatubes on the order of many tens of meters wide and high, many tens of kilometers long. These substantial lee voids are currently known only from indirect, yet *indisputable* evidence. Winding valleys, aka sinuous rilles, are a related feature, made from rivers of very fluid lava. Many rille valleys have bridged sections that suggests the visible valleys are near-surface lava tubes with collapsed roofs and that the “bridges” are intact tube sections.

Elsewhere we see winding chains of rimless craters that can only be collapse pits where parts of a largely intact lava tube below have fallen in. The inference is that elsewhere, there are wholly uncollapsed lavatubes. As the mare basin-filling lava sheets were laid down in distinct episodes with lava tubes likely forming in each layer, there may be many intact lavatubes well below the surface layers in some lunar seas.

Where are these lavatubes and their “lee vacuum” to be found? In the maria, mostly *near coastal areas*! While we are a long way from identifying all such features, we can locate a base in a coastal region with partially collapsed rilles in the likelihood of finding usable intact tube sections nearby.

Interregional travel considerations

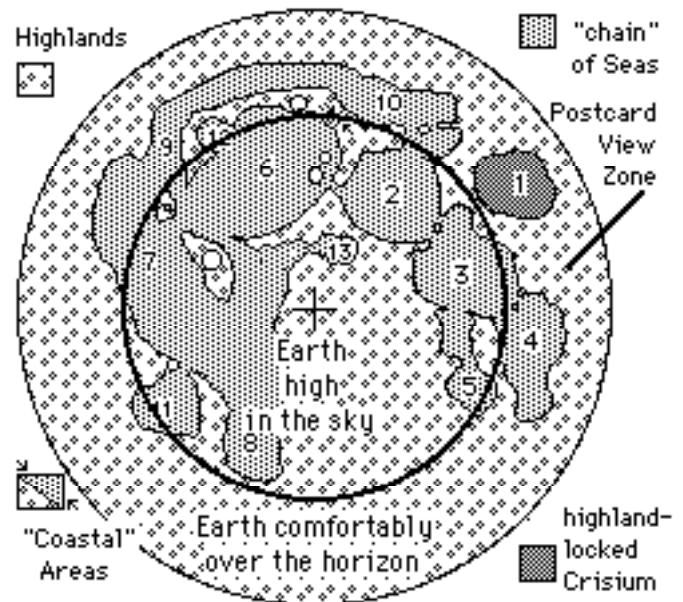
Quite a different consideration is ease of surface transport between a base site and other major areas of the Moon with comparable assets. A coastal site on one of the “chain” of mare basins on the Nearside seems best (leaving out Crisium and other highland-locked seas). On Earth some locations seem *born* to host major towns. To give a few examples, straights and narrows (Singapore, Detroit), major river confluences (St. Louis, Pittsburgh, Wuhan), major harbors (San Francisco, Rio de Janeiro, New York), lakeheads (Duluth), lake ends (Buffalo) and interlake constrictions (Niagara Falls), places where water routes and overland routes converge (Chicago) etc.

Now on the Moon, we have no bodies of water or waterways. But we do have a chain of Seas or maria *across*

which the going is easier - at least in general. Here and there on the maria, lava flow front scarps and rilles and occasional craters block arrow-straight travel, forcing bypasses. Places where such obstacle negotiation becomes easier recommend themselves as strategic sites. Coastal highland promontories and headlands (e.g. the cusps of Sinus Iridium in NW Mare Imbrium) are also route narrowing spots. There are “straights” and channels through which traffic *must* move, like the Alpine Valley that links northern Mare Imbrium and Mare Frigoris.

Craters with breached walls have interior assets more easily accessible than those of others. Passes through scarps and mountain chains also lure the town planners. Similarly, if highland-locked seas seem to include otherwise desirable townsites, there will be spots along their coasts from which a route through adjoining highland areas may be relatively easier to negotiate. Such spots too would claim attention.

A VERY CRUDE “MAP” OF NEARSIDE



- KEY:**
- 1 Mare Crisium, Sea of Crises
 - 2 Mare Serenitatis, Sea of Serenity
 - 3 Mare Tranquilitatis, Sea of Tranquility
 - 4 Mare Fecunditatis, Sea of Fertility
 - 5 Mare Nectaris, Sea of Nectar
 - 6 Mare Imbrium, Sea of Rains
 - 7 Oceanus Procellarum, Ocean of Storms
 - 8 Mare Nubium, Sea of Clouds
 - 9 Sinus Roris, Bay of Dew
 - 10 Mare Frigoris, Sea of Cold
 - 11 Mare Humor, Sea of Moisture
 - 12 Sinus Iridium, Bay of Rainbows
 - 13 Mare Vaporum, Sea of Vapors

The Alpine Valley between (6) and (10) lies between the arrows.

Summary

One site is not “*just as good as*” any other - except to one grossly unfamiliar with the Moon. We *could* know more than we know today before making a final selection. But if we carefully weigh all we now know about variously advantaged locations, we can pick a good site viable long term, even if the main thrust of industrial lunar activity occurs elsewhere.

It is perhaps decades too early to tell whether some twist in lunar development will add a strong tilt to this or that

location, perhaps even despite a low score on the test points above. A "go" for Lunar Solar Power Arrays on the E & W equatorial limbs would be one such all-bets-off eventuality.

Eventually there are sure to be a good plurality of developing settlement sites around the Moon. Our point then, is not to be sure to pick the very best site for the first outpost, but just to pick a site good enough to remain actively occupied well into the future. We need to take the task seriously, but not so seriously that we lose sleep agonizing over it. **MMM**

MMM #89 - OCT 1995

Sheltering the first Lunar Outpost

To create a true Lunar "Shelter", we have to come up with some way of putting several feet of moon stuff between our habitat complex and the naked Lunar sky. One way is to bag the loose lunar regolith and pile the bags around/over the base. For a full discussion of sheltering options ⇒ *below*.

More on a Second Look at Space Oases

This month, Dave Dunlop shares with us a "big picture" look at some of the space settlement questions raised by Peter Kokh and Doug Armstrong in their article in the July issue of MMM. Don't miss this essay. ⇒ *below*.

The *Philosophies* of Lunar Settlers

From Bryce Walden, Oregon Moonbase (bwalden@aol.com)

[This essay resulted from an exchange of opinion posts to artemis-list@lunacity.com among those interested in the Artemis Project™ - a commercial manned base on the Moon.]

"The human race will become a permanent presence in space when economic market forces drive us there." Well, yes, that's one way. But "economic forces" are just one of the possible motivations. For example, many American colonists left their homes and businesses in the Old World not because there was so much money to be made by going to America, but because they had philosophical or religious differences with their neighbors and found it more comfortable to leave, or even got kicked out by their neighbors! (I have a little list...) See below for more on minorities in a democracy.

Another motivating force to get people off the planet is fear. This was the motivating force behind Apollo, to display superior strength and skill to our feared opponent in the Cold War. For you ethologists, we would call this a kind of "posturing," engaging in postures demonstrating fighting or defensive skill without actually fighting. As such, a largely symbolic effort with no infrastructure development in space would satisfy the need. When that goal was achieved its scaffolding collapsed and we had to start all over again with the Shuttle, and now, finally, (maybe) a space station. The entire DOD space program is of course based on fear.

Fear of cosmic catastrophe could drive us offworld no matter how uneconomical it appears to be at the time. In that case, economics would follow settlement, not the other way around. This approach also has the added attraction that a mean-ingful goal would be to develop a completely self-

sustaining and reproducing society off the Earth. Anything less would not alleviate the fear that a cosmic catastrophe could wipe out humankind by destroying the environment of one planet.

As an engineering student myself, I can heartily sympathize with the advice to "Just Do It," build that hardware, and let the philosophy slide for some comfortable viddyside chat in Craterville. Alas, as Cheryl Lynn York (stardust@teleport.com) pointed out, "the philosophical question needs to be addressed." This came home to me when, to save a post on the subject, I telegraphed the filename to "Do, Then Think." When put this way, most of us would feel it is a bad idea. Just as we would not build a spaceship or a lunar base without a plan, we should not build a community without a plan.

The history of engineered communities is by and large a failure, however. Tightly engineered plans, such as Nazi Germany or Soviet Russia, sooner or later failed. There was also a serious failure of democracy in those countries. Nazi Germany should be a lesson in what can go wrong in a democracy (a situation said to be largely driven by economics, by the way). A good deal of the U.S. Constitution empowers individuals and minority groups to prevail against the greater voting power of the majority. The majority does not always win in a successful free society. Part of freedom is the maintenance and sustenance of diversity.

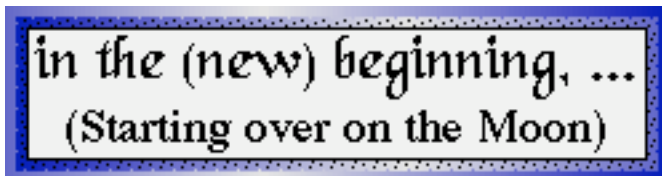
If we don't address philosophical issues both in the beginning and during development as they come up, we invite the development of social systems which we personally might not like, or might even find abhorrent.

All we wanted to do was go into space! But just as this new environment has forced us to grapple with new structures of matter and new ways of doing things, so it must spur us to better and more rational social planning. Ignoring this issue does not mean it isn't there.

Cheryl asks, "what *does* satisfy you as a next step? Satisfaction is a philosophical issue, like it or not." Psychology says to reward desired behavior. We need to establish a number of goals, many of which are achievable today, or within hours or a few years. Achieving goals rewards members of the organization, and helps everyone feel that progress is being made. Goals must be *both* achievable *and* objectively definable.

"Satisfaction" does not represent a well-definable goal to me, it is too idiosyncratic, and Cheryl wanted to know what goal would satisfy, not to suggest satisfaction was itself the goal. I like Ian Strock's idea that "satisfaction can only be achieved along the way--it is not a goal in itself."

The "goal" to be "satisfied" in the old L5 Society was simple and clear, to disband at a big party for all members on the first colony, presumably at L5, that could hold us all. Having simple and clear goals is a good idea. But that particular goal was so far in the future, and so difficult to achieve, that the greater experience people had with the organization was disappointment at never even coming close to achieving that goal. Although it was a good, simple goal, it wasn't enough. The means of achieving their goal was out of the hands of the members. They themselves could not achieve that goal. In a monkey experiment, this proved to be a great generator of ulcers in the monkey. **BW**



Last month, we talked about the tasks facing a first lunar outpost, and what it would take to clearly shatter the precedents and achievements of the 6 Apollo surface missions. Then we explored the role film making and other entertainment oriented ventures might have in taking us back to the Moon. Finally, we delved into the siting question: does it really make a difference where we put the thing? Of course, it does matter.

This month we return to the points of the first article, what achievements a first outpost on the Moon should strive to achieve, only this time delving into the many **technology** questions of realizing all this. There are lots of choices to make, and, as usual, some of the options will solve problems for the moment but lead nowhere, and other, more challenging options will be pregnant with the future. Enjoy!



“Digging in” for safe longer stays

by Peter Kokh

Relevant Readings from Back Issues of MMM

[Republished in MMM Classics #1]

MMM # 1 DEC '86, p 2, “M is for Mole”

MMM # 5 MAY '87, “Weather”

[Republished in MMM Classics #3]

MMM # 25 MAY '89, p 4, “Lava Tubes”

[Republished in MMM Classics #4]

MMM # 37 JUL '90, p 3, “Ramadas”

[Republished in MMM Classics #6]

MMM # 55 MAY '92, p 7, “Moon Roofs”

Other Readings:

“**Lunar Base Design**” by Peter Land, Illinois Institute of Technology, College of Architecture, Chicago, in “Lunar Bases and Space Activities of the 21st Century” pp. 363-73, Ed. Wendel Mendell, Lunar and Planetary Institute, Houston 1984, ISBN 0-942862-02-3

If an Apollo LM [pronounced Lehm] had remained on the Moon, it could not serve as the nucleus for a true lunar outpost. Its thin armor protected from vacuum only, useless against threats potentially just as fatal over the long term. A second much thicker layer of “firmament” is needed.

If human crews are to make extended stays on the Moon, they have the choice of being cavalier about the dangers and flippantly heroic. Or they can make sure their outpost is a true shelter and place of refuge from those characteristic lunar conditions that would inexorably work to do them in:

1. the big temperature swings between dayspan and sunlight, nightspan and shadow - thermal management in general.
2. cosmic rays incoming from all skyward directions
3. occasional solar flare storms with their intense radiation
4. solar ultraviolet, raw and unmitigated, during dayspan
5. the incessant micrometeorite “rain”

They can do this by covering their habitat complex with 2-4 meters (yards) of loose regolith soil. The amount or depth of desired cover depends on the longest crews are likely to stay during the lifetime of the outpost. Two meters will do for short durations of a few months. Four meters is better if you might stay the rest of your life.

Direct Shielding Methods

The first real question, at which not nearly enough discussion has been directed, is whether to apply the shielding directly, or indirectly. That is, do we just use a drag line or bulldozer to cover the habitat complex itself? Or do we build some sort of hanger shed, cover that with moondust, and park our outpost modules underneath. Both have pros and cons.

The direct method is undoubtedly easiest and the most simple, requiring only soil moving equipment which will be needed in any case. If you want to keep the costs and weight of the first return mission down, you might consider this method.

It does have drawbacks! How do you add on later to an already buried complex? Leave the expansion end uncovered? One way, proposed by the University of Houston’s Sasakawa International Center for Space Architecture, would be to first fill “sandbags” presumably brought along from Earth, with lunar soil, and then stack these around and over the complex. When you need to uncover a section for maintenance or expansion purposes, you just remove the bags in that area and replace them later. An elegant solution.

There is a cost, of course: (a) the bagging equipment, (b) the extra weight of the bags themselves. Eventually such bags might be woven locally of lunar fiberglass - would bringing along the equipment to do all that that be more of an expense than just bringing along ready made bags? If you would break even the next time, or the third time, you brought up an expansion module, would that be worth it? That’s a question worth looking into. Certainly, we must always look beyond the needs of the mission of the moment!

But there are other disadvantages of direct shielding, in any form. These are not clear, however, until we look into indirect shielding and learn what fringe benefits it allows.

ORPHANED HOMEWORK:

- (1) a (student?) engineering design competition to flush out the most elegant ways to cover a complex with regolith soil, with the lightest weight equipment, allowing one lunar dayspan (14.75 days) to get the job done.
- (2) Design sturdy, durable, closable, yet lightweight bags that can be brought to the Moon in a compact form.
- (3) Design equipment to weave lunar fiberglass threads into

serviceable and closable bags that will hold the fine powdery soil. (Automated equipment to produce glass fibers and glass composite mats has already been brainstormed by Space Studies Institute, Goldsworthy Alcoa, and McDonnell Douglas. The equipment needed would weigh several tons, but pay for itself, in import tonnage defrayed, rather quickly.)

Indirect Shielding Methods — SHED / HANGAR

Building a dust-shielded “hangar” that provides large unstructured “lee vacuum” space in which pressurized modules can be “parked” in various forms of juxtaposition and interconnection, offers a much faster, and easier way to set up an open-ended expanding modular outpost. There is no shielding to remove when adding additional modules, nor any directly applied shielding to interfere with servicing and repair of systems with components on the exterior of modules or nodes.

As a bonus, there is extra radiation-free, UV-free, micrometeorite-free, and flare-proof unpressurized “lee” “service” space for storing tankage and other routinely needed, frequently tended equipment that does not need to be exposed to the sky. This in turn allows the wearing of lighter weight pressure suits for these kinds of “exterior” housekeeping chores.

The hangar shed makes sense if there is firm, review-proof **commitment to phased expansion** of the base beyond the original bare minimum habitat structure. For while its construction adds an original base-deployment “delaying” mission or two, the time- and effort-saving dividends down the road are considerable. If our commitment is scaled back to putting a toe in the water, rather than to a wholesale plunge, then, of course, the hangar will be seen as unnecessary.

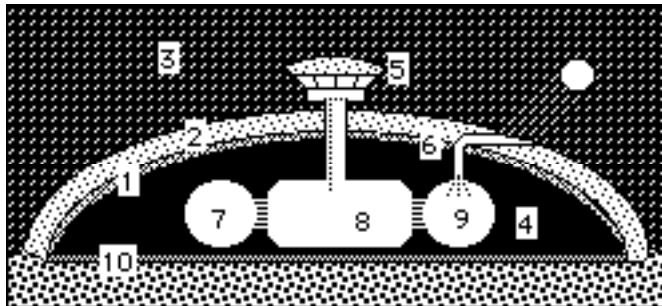
A hangar can be built in many ways. A **pole and “canvas” tent** structure can be covered with loose regolith. Alternately, an arched space frame structure can be built, covered with a fabric, then overfilled. A less dead-end, more pregnant approach, at least with a view towards incipient lunar industrialization, would be afforded by brining along molds and a solar concentrator to make sintered **arch component blocks** out of regolith soil. These could be stacked over an inflatable semi-cylindrical bag. With the completion of an arch section, the bag “slip-form” would be partially deflated, enough to move it over a bit, reinflate it, and support the building of the next arch section. In this way, a little bit of equipment from Earth would allow indefinite expansion of lee space shelter using lunar resources entirely.

This slip-form sintered arch-block approach is well-developed in the paper “Lunar Base Design“ by Peter Land of the Illinois Institute of Technology, pages 363-73, in “Lunar Bases and Space Activities of the 21st Century”, Ed. W.W. Mendel, Lunar and Planetary Institute, Houston, 1984.

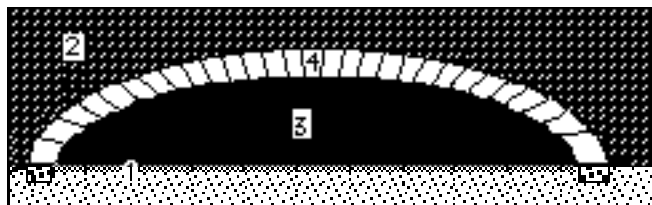
The ‘ground’ under the arch (the floor of the hangar) can be graded smooth, compacted and sintered to provide a relatively dust-free apron for the sheltered outpost. As we will see in a later article, “site management”, dust control, and good housekeeping habits must be in place from the gitgo if our attempt to establish an interface beachhead is not to fall flat on its face. (Inner and Outer “Yard” Managers or yardmasters will be critical job slots.) The hangar approach favors the early adoption and rigorous pursuit of good *homesteading* habits.

The hangar interior can be **naturally lit**, during dayspan, by providing intermittent broken-path sun-wells or direct path sun-dows made of bundled optic fibers which double as shielding. Electric lighting for nightspan can be separately suspended from the ceiling or placed above the exterior surface, to use the in-place sun-well or sun-dow light delivery system.

Visual access can be accommodated by broken-path (radiation-proofed) mirrored shafts from the habitat modules underneath through the hangar roof. With proper planning, such ready-access observation ports can be provided ahead of time as the hangar is expanded section by section. Alternately, a pressurized vertical ladder-shaft can lead from habitat below to pressurized observation dome on the hangar roof.



KEY: (1) Space Frame Arch, Fabric Cover; (2) 20 cm or more regolith dust shielding; (3) exposed vacuum, radiation, micro-meteorites, UV, solar flares; (4) protected lee vacuum service area; (5) observation cupola with ladder shaft to habitat space below (7, 8, 9); (6) broken-path solar access via heliostat and fresnel lens diffuser; (10) compacted, sintered hangar apron



Arch-Block Hanger KEY: (1) compacted, sintered hangar apron; (2) “Weather”-Exposed Vacuum; (3) Shielded “Lee” vacuum; (4) self supporting arch made of blocks produced from sintered regolith in simple single shape mold, applied over an Inflatable Slip Form.

Hangars can be open for expansion at just one end or at both ends. The latter ploy makes more sense and provides greater expansion-vector flexibility.

The hangar approach can be called the twin or **Two Firmament Strategy**. Sheltering from exposure to the “weather” of the naked lunar skies is handled separately from sheltering from vacuum. An initial “umbrella” firmament is built first and allows a wide range of architectural freedom and plan revision for subsequent base expansion underneath.

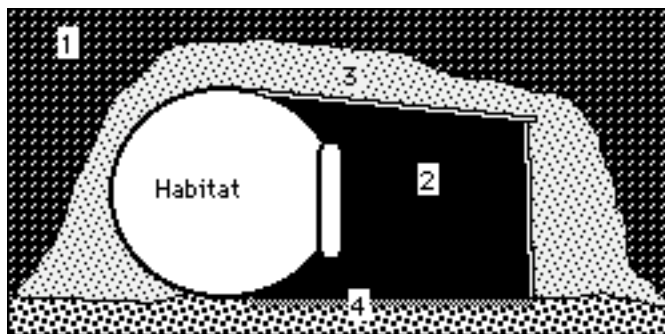
In contrast, indirectly shielding individual habitat structures can be called the single, or more aptly, the Joint or Laminated Firmament approach. As usual, impatience quickly proves to have resulted in an unfortunate, option-preempting choice. The Two Firmament approach better embodies the philosophy of the base serving as an “interface” between Moon and Man.

Implications for Lunar Industry

By this scenario, lunar sinterblock and possibly cast-basalt paving slabs, not oxygen production, become the first lunar industries. (Using lasers or microwaves to fuse soil might be another option.) If a space frame approach is used, the manufacture of sintered iron rods and/or of glass composite rods and fabrics would become early industries. The pros and cons of both approaches have to be weighed.

Hangar alternatives

If there is no firm commitment to phased expansion, but merely a concession to “leaving the door open” to further expansion, a half-measure would be to directly shield a habitat structure with an attached side or front “carport”/service area. This approach provides the benefits of attached lee vacuum. As to future expansion, the docking port for parking an added module can be included under the carport or under a separate shielding “retaining collar”. Obviously, this is a “consolation prize” approach and not the way we should be planning.



Directly Shielded Habitat with Carport/Service Area Shed:
KEY: (1) Exposed Vacuum; (2) Sheltered Vacuum of Carport;
(3) regolith blanket 2-4 meters thick (4) compacted and sintered floor of carport, part of dust-control strategy.

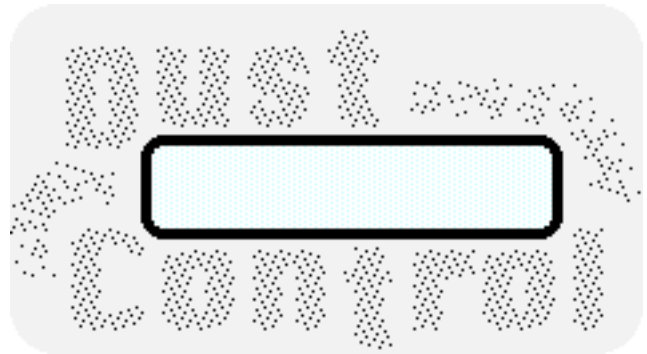
At the other end, much more ambitious than the hangar, is to place the outpost in a pre-located lavatube. This may involve major up front costs of brining along boring equipment for elevator shafts, and personnel/freight elevators themselves. Lavatubes have great promise, but they seem dauntingly challenging for an initial beachhead establishment venture, posing problems of easy access, floor rubble clearance, and possibly ceiling reinforcement.

In all this discussion, NASA preparation earns a C grade. Johnson SC has looked into both bagged shielding and inflatable structures. And through its space architecture university support programs has furthered studies of lavatube utilization. But much more needs to be done to isolate and identify the most promising alternatives for hangar architecture, weighing heavily those methods that give the biggest and earliest boost to lunar industrialization and use of local resources for further expansion.

NSS could apply some remedial assistance with a sequel to its '99-'89 Space Habitat Design Competition. The design constraints and objectives would have to be clearly defined, looking for maximum use of local materials, minimum need for one-use only import materials, low weight import capital equipment, and adaptability to automated or teleconstruction methods. We'd need a donor/donors of prize incentives sufficient to attract suitable talent. *And follow up publication of results (not like last time!).*

RECAP

Apollo left no occupiable structure on the Moon. There is no 'friendly' place to return to, no place where we can go and pick up where we left off.



Not all the physical aspects of the Lunar Environment that can fatally threaten a Human Basehold are “Skyborne”

by Peter Kokh

The problem with moon dust

The evidence from our six limited Apollo Mission engagements on the surface of the Moon is clear enough to be worrisome. Fine moon dust particles clung to spacesuits and tools and samples electrostatically, resisting brushing off. They found their way into all crooks and crannies of the lunar modules, even into the Apollo Command Modules into which the returning astronauts, their tools and samples, transferred.

These particles are “unweathered” and thus have sharp edges. They include an abundance of micrometeorite-produced glass spherules. There is good reason to believe that without aggressive countermeasures and “prophylactic strategies”, they will accumulate in pressurized interiors to the point they foul up machinery, computer keyboards and mice, control panels and more. Some fear that inhaled moon dust could lead eventually, in extreme cases, to a sort of silicosis in the lungs.

Clearly, this is a potential problem of such scope that we cannot afford to treat it casually. It won't just go away. *On the other hand*, past human experience with sundry troublesome aspects of newly settled territories shows that most such problems soon become minor. *We learn* ways to deal with the problem that become second nature. In due course, bad effects diminish to the point where they are below the threshold of everyday concern. It becomes a matter of special habits - habits, if you will, of *good housekeeping and good “hygiene”*.

Moon dust, as a problem feature, would seem to be susceptible to a two-pronged approach: proper design of the **structures** and the **equipment** by which we interface directly with the host lunar environment. We must brainstorm our strategies well in advance of our return, adopting a broad spectrum of promising tactics in the design, deployment, operation, and maintenance of our outpost from the outset - or risk an ignominious, dishonorable surrender. **Dust Control Strategy** must be part of Moon Base Design - and not in some token squeak-greasing afterthought manner.

Architectural Countermeasures

In the previous article, we saw that grading, compacting, and sintering the near surroundings of our outpost struc-

tures is cheap insurance. Not only airlock and dock entries areas are kept *relatively* dustless but also the yard space where frequently accessed equipment, stores, and systems are housed. This suggests itself naturally in the erection of hangar sheds, but is a less obvious consideration, temptingly forgotten, in the direct deployment of individually shielded habitat modules.

Sinter-paved areas should be separated from untamed dust areas by access over grate-covered dust-moat trenches. The idea is to *put the shoe- (and tire-) cleaning welcome mat as far out from the actual outpost entrances as possible.*

Site Management must consist of more than “fixing” the regolith in entry apron and service areas immediately surrounding the outpost. Every regularly trodden and driven approach should be sinter-paved, by a method appropriate to the weight loads that will bear upon it. Pockets and preserves of natural moonscape terrain should be left for the areas and spaces between such paths. This will be a matter of landscape architecture and design in consultation with the Inner and Outer Yardmasters, to meet their needs. Ignore or dismiss all this and we will surely repeat the cluttered unkempt chaos surrounding McMurdo Sound in Antarctica, exposed by Greenpeace to our national shame and embarrassment.

There are limits to the effectiveness of such tactics. But without such dust containment zoning measures in place, *anything else we try will not work at all.*

Engineering Countermeasures - Suit-Locks

The presently conceived airlock, and the spacesuit types now on the shelf, have no place in any serious effort to make ourselves at home on the Moon.

Ben Bova, in his 1987 slow-selling “Welcome to Moonbase”*, describes a “car-wash” type airlock in which incoming dust-laden astronauts pass through an “electrostatic shower” before entering the habitat proper. This would be an expensive piece of equipment, adding appreciably to the cost of lunar operations and settlement, if, as seems likely, it would have to be installed in each and every airlock!

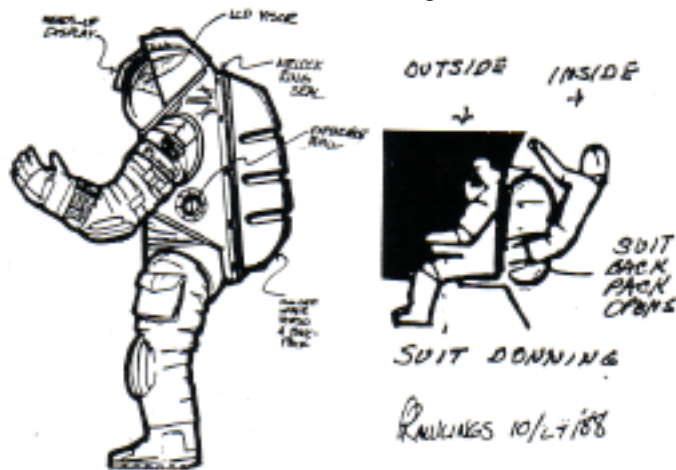
[* Ballantine Books, New York, ISBN 0-345-32859-0, \$9.95]

Pat Rawlings who did the illustrations for the book has elsewhere illustrated a much better dust-control approach. The cover of “Lunar Bases and Space Activities of the 21st Century”** shows personnel wearing what I have come to call the “Turtleback” suit, in which an oval hardshell backpack covers the torso and back of helmet. This backpack is hinged on one side, and entry to the suit is made through the opening.

[** W.W. Mendell, Editor; Lunar and Planetary Institute, Houston 1985, ISBN 0-942862-02-3]

In pre-release conceptual illustrations Rawlings did for the David Lee Zlatoff/Disney/ABC ‘91 movie “Plymouth” (still the only science fiction film ever made about settlement and the idea of using lunar resources), there are sketches of turtleback conformal airlocks (my words) into which this specially designed backpack makes a sealed connection, then swings open, allowing the incoming astronaut to (pulling his hands and arms out of the suit sleeves) reach back and up through the opening to grab a bar above the inner door of the lock and pull himself out of the suit and into the habitat. The suit and most of its dust remains outside, perhaps to be stored automatically on an adjacent rack. Whether Rawlings himself

ever thought through his artistic concept this far, or further, is unknown to this writer. But we want to give him full credit.



We need to radically redesign both spacesuit and the airlock, co-defining and co-designing them to work together to keep dust outside all pressurized areas.

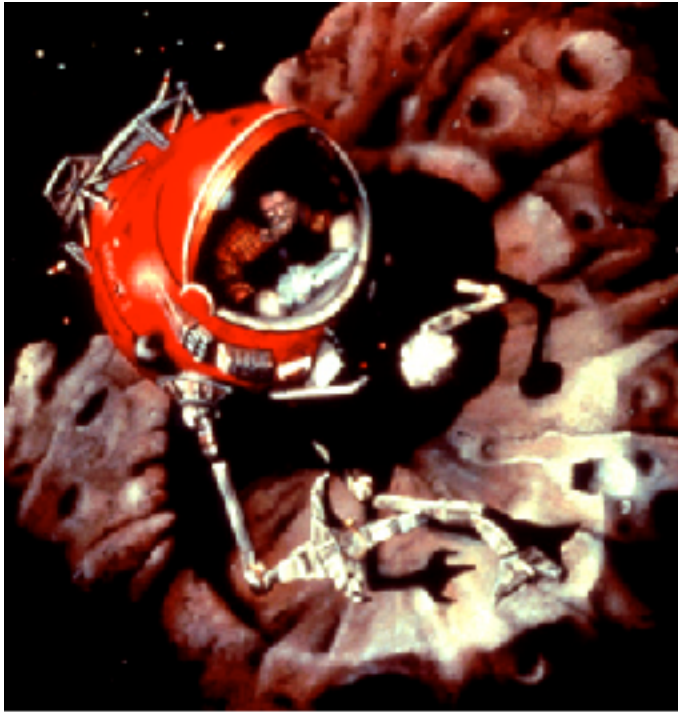
We will take up this idea and the several engineering challenges it poses in a separate article, hopefully next month after we speak on it at the upcoming MSDC and gather in some helpful feedback. For now, we just wish to point out that we must totally rethink airlocks - and what we allow inside the habitat - as essential to successfully tackling the dust problem. And this promises to be a far cheaper approach, certainly in the long run. Such “suit-locks” will be features not only of pressurized habitat modules, but also of pressurized vehicles. It is a **whole new language** of how to handle the pressurized/vacuum interface in dusty locations on planetary and asteroidal surfaces. It is a language in which spacesuit and airlock are co-defined and codesigned - far from the present case!

The “Dock-Lock”

In addition, we need to equip *everything, vehicles and habitats alike*, with unisex “dock-locks” for “shirtsleeve” passage (on the pale analogy of the airport “jetway”). The ordinary traveler on the Moon need never don a suit to leave his abode and go to another habitable location *anywhere* on the Moon. **This will establish a very real virtual continuity** between all habitable volume on the Moon, mobile as well as stationary, however actually discontinuous our lunar presence may be. Through this sort of pan androgynous interconnectability, every vehicle and every structure on the Moon will be **interchangeably contiguous**.

And introducing the “Buppet”

Other considerations, like safety and comfort, will work to minimize the need to don spacesuits at all, in most routine activities. The “buppet” (whole-body puppet) is a one person (probably but not necessarily ambulatory) hard shell conveyance with hand-operated manipulators which allows its operator to do field work in shirt-sleeved comfort, with full ability to scratch an itch and whatever when needed. It would be entered through a “dock-lock”, again leaving most of the dust outside. Such a “buppet” (my word) was beautifully illustrated (with what looks like me inside, complete with my plaid flannel shirt and beard!) on the cover of the June 1985 of the *L5 News*.



An Appropriate Space Environment for Man

by David A. Dunlop, LRS, LUNAX, WSBR

In the July Issue of MMM, Doug Armstrong and Peter Kokh discussed the space architectural forms of the cylinder, torus, sphere, and helix geometries of space settlements and the economic argument that the cost feasibility of developing such structures is dependent on a phased pattern of growth in small cost-feasible steps. Further extension of this argument was made based on a broader range view of the gravitational standard that is "acceptable" in such designs.

A more basic beginning question should precede all such specifics and serve as a guide to the quest for development solutions. *What is an appropriate environment for man?*

Design Requirements: That question is both a question of design and an question of identity. It can be rephrased as Man is the animal that needs _____x_____ .

- a certain amount of water per day
- a certain amount of oxygen per day
- a certain mix of atmospheric gases
- a certain range of air pressure
- a certain amount of calories per day
- a certain amount of specific nutrients per day
- a certain amount of square footage and volume
- a certain temperature range
- a certain range of gravitation force
- a certain range of radiation exposure
- a certain set of architectural forms
- a certain set of psychological characteristics
- a certain set of behavioral characteristics
- a certain set of socialization practices
- a certain set of social forms of organization:
 - family structure
 - work structure
 - recreational structure
 - political structures etc.

When you get to the end of the laundry list you add up the factors and have the environmental answer as to what is appropriate.

Space Settlements: A Design Study (1) This NASA publication of the mid 70's has a section which provides a range of minimum values or design requirement used in urban design. These standards for human urban environmental support system whether we call it space oasis, town, city, are the most obvious set of considerations. They include characteristics such as minimum area per capita of living space, the number of gallons of water per capita per day (far beyond life support minimum requirements by the way), a per capita amount of power consumption, a formula for open space and public transportation space in relation to all enclosed buildings and so forth.

The Political Economy of Design Toward the Short Term: However this use of such design laundry lists is in the initial stages confronted by the "practical" realities of:

1. What we can afford
2. What we can technically provide.

All these new proposed contraptions may seem very interesting. What is sobering is that they are more than just interesting - they are necessary - and there are no plans afoot in NASA, industry, or for-profit lunar return efforts to make them real. Alarmingly, almost no one suspects such radical redesigns are necessary. No one seems to be aware that without the right equipment to make good "housekeeping" and "dust-hygiene" automatic and thoughtlessly easy, we will inevitably lose the battle with moon dust. Our initial outpost will become unlivably befouled with the stuff far faster than the interior walls of MIR became coated with organic grunge. Being in such a hurry to return that we put dust control on the back burner or plan to treat it with various ad hoc afterthought measures is a prescription for disaster.

Even had we the habitats and cheap transportation to get them and ourselves back to the Moon, we are a far ways from ready to set up a moonworthy beachhead. We give NASA a Grade of D+ for Dust Control. The venerable agency's anti dust strategy is woefully inadequate to handle the problem and if implemented across the board (i.e. the electrostatic "car-wash") will be very expensive, hogging a disproportionate amount of throw weight and pressurized space. Stitch in time saves nine. Junk the spacesuit. Junk the airlock. Don't take a "can't do" attitude towards turtlebacks and suit-locks. We need a must do attitude. "Failure is not an option"

Implications for Early Lunar Frontier Industry

For the foreseeable future, such things as turtleback suits, suit-locks, dock-locks, and buppets will have to be manufactured on Earth and shipped to the Moon. But the accompanying strategy of making dock and lock entry aprons and approaches as relatively dust-free as possible, implies that sinter-paving, regolith-fusing, cast basalt, sintered and/or cast iron become introductory lunar industries - from day one, necessary to the proper complete setup of lunar operations. As obvious a priority as oxygen production is, that must come second. If no one heeds, we stand to fail.

MMM

What we "can" afford is in the short term always a political decision. Since the focus on the short term is the most consistent view, the long term requirements are not often well understood until the failure to provide for them has produced failures or problems whose short term significance was not realized or was denied significance in competition with the more "obvious" necessities. This after-the-fact understanding is often the most expensive way of learning the consequences of consistently focusing on the short term "practicalities."

What can be technically provided is another major practical constraint. Our rockets can lift only so much mass and can loft structures of only so much volume. These constraints are the main drivers of design discussion. When we "can't" provide something in the short term and we are "forced" to do without it in the short term, the accountants and cost-efficiency analysts are tempted to ignore as a practical matter *that we must provide it especially in the long term but can't say exactly when.*

Yet these practical constraints also beg the larger questions of *what is the acceptable or even optimal environment for man?* Here in the good ol' U. S. A. and especially in the central cities the lack of job opportunities, the lack of positive role models, the difficulty of easily obtaining jobs for livable wages, the difficulties of financing educational opportunities throughout the lifespan, result in a continuing wastage of human capital. This can be measured in terms of opportunity costs and in actual costs of crime, illness, and higher levels of police, fire and corrections costs, the instability of family structures and the problems of poor socialization practices of children.

These tradeoffs have been long understood but little acted upon in earthly urban environments. That human behavior is to a significant extent environmentally determined is well understood scientifically but most often not successfully defended politically. This is true when the individual's share of public expenditures for such matters on one hand are put against individual consumption prerogatives on the other.

The larger context of Environmental Requirements

This question however is still limited by its egocentricity. To define the environment which is appropriate for man in only humanocentric terms is at odds with our history as a species. As Kokh and Armstrong appropriately pointed out over the historical record the environment has changed, and man has changed with the environment. The question has been a continually moving target in evolutionary history. In the evolutionary context we define man in term of his adaptation within an environmental system, an ecosystem of which he is a small though significant part. One cannot properly understand man, man's needs, indeed man's identity itself without this larger context. This need of the larger context is just as true of the laundry list of physical requirements for sustaining man, as well as for the psychological requirements of individual identity and meaning, and well as for the sociological meaning, and political purpose.

Historical Models and Long Term Standards

In the Judeo-Christian religious sphere, man in the Garden of Eden has been defined as the creature whose job was to take care of the Garden of Eden and whose purpose was to

fulfill the will of God. In these statements man is defined in terms of the larger context - not the larger context defined in term of man. Yet it has been a most persistent trait to slip into defining the universe in terms of ourselves and it has taken millennia for us to discover our true insignificance in the cosmic scheme of things, thanks to Copernicus, Galileo, Kepler, and Hubble. This discovery continues today, in which our most elegant notions of universe are confounded by significant discrepancies in our model of missing mass, the age of the cosmos, and the difficulties of construction of an integrated model of elemental forces.

In the area of environmental support systems, NASA studies have acknowledged that physicochemical systems are over a 10 to 15 year period probably less cost effective for a small number of humans than a more complex bio-regenerative closed environmental life support system. We will "better" solve the problem of regenerating the oxygen/CO2 balance, of purifying the human liquid and solid "wastes", and providing the variety of biomass nutrients needed for sustenance with an environmental systems of 10 to 15 plant species which have complementary support requirements that interlock with these physical requirements of man.

This "engineering" conclusion seems so self apparent from an evolutionary context that one may wonder why it deserves comment. For one, it ridiculously understates the ranges of plant species that are necessary for long term sustenance of human populations. A suggestion of a 10 to 15 plant species solution to environmental control systems should be considered only a short term solution to an early phase of a development which will last for many generations. The construction of a sustainable biosphere off the Earth is at least the equal in our time to the task of cathedral building in the 10th or 11th century.

The Tyranny of the Short Term Standard

Of course when we start talking about what we "can" afford to fit on a rocket, we tend to immediately revert to the laundry list and then ignore the long term requirements of psychological identity, sociology, and polity much less the grandeur and "grandiosity" of mentioning ecosystems requirements or definition. Because these definitions are so daunting in both complexity and scale they are basically ignored and defined out of the laundry lists that must be taken "seriously" in the short term. Such deferrals in the short term are hard to overcome in the "next" short term list, and so on. This is how the lack of a much larger system vision condemns us to short term expediency and its propensity toward significant design errors and omissions.

We seem to have lost culturally the capacity that existed during the middle ages which concerned itself with "meeting the requirements of God" even if it took generations to fulfill such requirements. The constructions of the great Cathedrals of Europe were the work of centuries spanning many generations. *No such clear sense of over arching necessity or purpose exists today for any national or international project which enlivens our designs.* Instead we have the increasing anxiety about the need to create or preserve a "sustainable" future for our economy and our environmental system as a reactions to the accelerating destruction of environ-

mental resources. We aspire to preserving a planetary Steady State! We don't aspire to visions of new worlds. The output of enormous effort in the here and now that will not see completion in one's lifetime is a very alien and even humorous idea in an era which is increasing conditioned to short term expectations of accomplishment and maximized individual consumption. In the 1930's Roosevelt's vision for society was "two chickens in every pot." in Eisenhower's it was two cars in every garage. Today in the U.S. our vision seems to be focused on hanging onto our declining standard of living. We no longer seem to be "on the make."

This loss of the "larger context" is reflected in the accounting system which defines the concept of useful life in terms of depreciation schedules which range from a 3 to 5 year period on "short term" consumables to a 30 year "long term" mortgages for a house. Practically speaking the financial system has no schedule for valuing in numerical terms and financial terms periods of depreciation over 30 years. "Nettle-some" considerations are ignored or defined as "externalities." A corresponding change has been the focus on immediate consumption and the corresponding decline in the rate of savings. This loss of psychological and sociological software is as significant in terms of its functional consequences as the failure to provide for an adequate water supply.

The Value of The Grand Vision and the Long Trajectory

When the opportunity arose for the purchase of the Louisiana Territory from the French, the amount represented a substantial portion of the entire budget of the United States in 1805. Yet Jefferson, *looking ahead over the course of a century or two*, realized that the purchase price was an infinitesimal portion of the true value of what was being offered. Against opposition he persuaded the Congress to take the plunge. On a smaller scale "Seward's folly of purchasing Alaska for 67 million dollars in the mid 1860's was another such uncommon example of the long term view prevailing. The economic wisdom of Jefferson and Seward is now clearly apparent after well over a century has passed; but the territorial gain and economic gain of other planets, the Moon, and Mars has eluded every President and Congress since Nixon!

In the matter of designing space oases the accountants and engineers have controlled and dominated the discussion and therefore the designs. The political position of these groups has been such to portray these space enterprises as being cost-infeasible. This consideration has led to the morass, stagnation, and failure of this generation to aggressively pursue the Apollo initiative.

It would appear clear today that stabilization of the global population, a sustainable environment, and a sustainable economy providing a high standard of material well being to everyone on Earth, cannot be achieved without relying heavily on the use of space-based material and energy resources.

Kokh and Armstrong argue that the "classical" space settlement megastructures were too overwhelming a goal to approach. I would argue just the opposite! *The "mega structure" of the sustaining ecosystem for man is the only place to start because it is the larger context which demands a more realistic view of the longer context* in the accounting system of our species *and* our immediate politics.

The design considerations from the start must consider the evolutionary trajectory!

The Gravity Standard

Let us take up to matter of the standard of gravity and the enormous impact on mass and initial costs such gravity standards imply that was raised in the article. At present we do not understand the range of gravity that is necessary for the sustenance of our species either above or below 1 G - except that it seems clear that 0-G conditions are not sustainable biologically for our species because of the extreme debilitation of the cardiovascular systems and bone tissue density that we have observed from "long term" space flight which is currently defined as less than two years! Even such short term exposure to 0-G seems to threaten the individual with significant debilitation which may be irreversible.

Without some real experience exploring this question there is no intelligent position that can be taken on where limits below or above the 1-G level should be set. Kokh and Armstrong are absolutely correct in the evolutionary context to demand that the limit be pushed in consideration of design options. We may indeed find that a standard of 1/6th G or 1/3rd G is viable for our species. If this is so, it may mean that a considerably smaller scale of mass is necessary than would be the case for a strict 1 G standard. However they have fallen into the trap of accepting the limitations of the accounting and engineering elite that has stagnated our current space effort.

If it turns out that our species does indeed require a 1 G standard or a narrow range thereabouts which necessitates a 1000 meter rotating structure or a 5,000 meter rotating structure *then that is what must be built!* Even if it is the work of 5 presidential administrations! or five generations! Our financial conclusion should be to accept a longer time frame to achieve what is necessary, not to abandon the effort as financially impractical.

If we had made the commitment to build the space station pictured in the 1968 film *2001: A Space Odyssey*, we might actually have had such a station in existence by 2001 almost two generations later. Since our commitment was not made to a "magnificent grandiosity", we could not hang onto sky lab, design a shuttle effective to realizing such a station, or more sadly see that station in *its proper context* as a stepping stone to yet a larger ambition. The requirement of such an effort has clearly been within the national technical capability in term of freeing up sufficient numbers of specialists from the sustaining requirements of food productions and other material necessities of the U. S. economy. We have sunk at least that much effort into the Cold War, especially if one views what has been produced and purchased globally in the arms trade since Apollo.

The Value of Animals

Indeed in the real U.S. economy we have sunk that much effort into the purchase of dog and cat food. In fact is it not curious that we deem the companionship of our pets as so important to us in the short term that as a society we refuse to invest a similar scale of effort into the long term survival and expansion of our own species. It is also ironic that few of the utopian visions of man in space put much stress on the companionship of animals. Forgive me! Commander Data

has a cat! I was alluding to those more serious biosphere II designs which concentrate on talapia fish and Vietnamese pot bellied pigs! - or NASA Moon Base scenarios devoid of animals. Might not the psychological ministrations of a dog or cat just be crucial to the long term mental health of many of its human occupants and therefore of the stability and survivability of the oasis? I have heard no discussions of any "serious" mention of pets in the context of a Lunar or Martian base. Pets you see are a frivolity that have been left off the "serious" list. If they appear it will be most likely a justification that they are needed as "lab" animals for biological research, and not because they are important to have around in their own right.

The biological, psychological, political and eco-systems requirements of our species expansion are truly vast in relation to the existing planetary economic base on which we stand. But the gains of planetary expansion to the Moon, Mars, and planetesimals, so completely exceeds the efforts required to obtain the gain that the present limitations of the accounting systems must be revised to a more realistically modeling of this economic potential. The Apollo missions were planning for a few camping trips. We must now plan for an invasion! Only this scale of thinking will be productive!

The Value of Biodiversity

The state of the art hydroponics practitioners claim that 60 to 70 square meters will produce a sustainable basis for human food production in a space agricultural system. This is a very minimal standard that takes a very narrow view of the requirements for biodiversity among the set of supporting species needed by man. The need for variety and diversity can be suppressed for only so long. Such "standards" are merely concessions to the expedience of short term and somewhat arbitrary constraints which are primarily political decisions on short term resource allocations.

In exploring grandly the questions of "What is an appropriate environment for man?" in the context of space environmental design and expanding this consideration toward factors which might be considered "optimal", we can gain the greatest immediate spin-off possible. That spin-off is better management and a clearer vision of what are our systems requirements for this beautiful planet, ourselves included. It is in gazing out toward the long term future of humanity that we may gain the best mirror of our self as a species and the more humble and wise understanding of the vast system of which we are one small but integral part. When we look at how our current economic, political, and planning systems have failed to adequately address these questions of what is an appropriate much less adequate or optimal environment on Earth we have to carefully and skeptically look at a minimalist approach to such questions in space. In this context I am not about to apologize for the label of big spender. Both the demands of entering the environment of space, the time demands of doing so, and the potential returns on the investment require our species to be a big spender. The size of the debts is balanced by the size of the assets!

DD

The parachute was invented more than a century before the airplane.

MMM welcomes Artemis Society International

We end our 9th year of continuous publication on an up-swing, welcoming the nearly 300 members of ASI. Headquartered in Huntsville, Alabama

This non-NSS group has a focus compatible with ours. "We are dedicated to overcoming the business, financial, and technological challenges necessary to establish a permanent, self-sustaining human presence on the Moon" says ASI President, J. Boise Pearson.

This development is a good deal for MMM chapter members, as it promises to lead to a series of *upgrades in both the appearance and quality* of this newsletter.

Welcome Artemis Society Members!

You are now receiving **Moon Miners' Manifesto** as a membership benefit. MMM will carry Artemis Society International news and announcements in the **Pleiades** centerfold supplement, as well as articles contributed by ASI members.

MMM has a long *reputation* for a great mix of fresh reasoned speculative articles about our future on the Moon (occasional theme issues on Mars, the asteroids, and space settlements), space news, and member/group announcements. We do not carry articles or letters dealing with inside politics, preferring to spend precious energies in more productive ways. You will like our repeated *emphasis* on private enterprise and entrepreneurialism. We share your view — we want *people in general* in space, not just token public scouts!

You are **sharing this newsletter** with members of eight (of eighty-some) local chapters of the National Space Society, a nonprofit membership organization like ASI with a *compatible and complementary focus*. NSS' goal is "the establishment of a spacefaring civilization with human communities beyond Earth". But the approach differs in that it concentrates on public outreach and political advocacy of legislation to help remove obstacles and to facilitate commercial space endeavors as well as to promote a more vigorous national space program.

The MMM staff in Milwaukee thinks this is a great deal for all involved. The doubling of our circulation will lead to a series of upgrades in the appearance and quality of MMM, which next month begins its *10th year* of uninterrupted publication, month after month after month, with you on board!

While MMM comes in as a pinch-hitting replacement for **Pleiades**, Artemis' own newsletter which got off to a shaky start, we hope we hit a home run in your ballpark. With the help of Artemis' resources and connections, we can look for MMM to get better and better.

Enjoy! PK

in the (new) beginning, ... (Starting over on the Moon)

This month we continue our discussion of absolutely necessary but inevitably impatiently overlooked aspects of base setup. We either take heed and plan accordingly, or we go through yet another false start. Then we begin discussion of the first milestone of “permanent” presence on the Moon - *getting through* that first of a forever series of two-week long night-spans. And more!

MMM



by Peter Kokh

It's simple, really. We just plop down a basic habitat module and throw some moondust over it for good luck, add some solar panels or a small nuke, a radiator, an antenna, and a rover — and, *voila*, we have a Moonbase! Whoa! Doesn't that leave a lot of unanswered questions? How will our little baby develop? Are we going to be so quick to show around the latest snapshots of our offspring a few years down the road?

Will future growth and development of our little bundle show that it had “good genes”, or “bad” ones? A well-thought-out site management philosophy with a full deck of guideline zoning protocols, in place from day one, will help guarantee that we will be proud parents, not just shortly after birth, but well down the road. That's adding “good genes”. If we fail to do this, or put it off as unimportant, the future of our creation will be “amorphous”, and since corrective and reactive measures are never as effective as proactive ones (and always too late), an unhappy McMurdo-style mess is sure to result if we don't care enough now - while we are planning.

If a definite site, mapped from orbit down to near meter scale detail, has been predetermined, then our site management plan can be quite specific in its initial design, with zoning of the immediate vicinity well thought out. One would hope this is the case.

If, however, we have only a general location in mind, we'll leave picking the actual site up to the good judgment of the pilot of the lunar descent vehicle bringing in the first load, then all we can have prepared is a manual on the “General Principles of Lunar Base Site Management”. This is how the Apollo landing sites were picked: neighborhood by NASA, block and lot by the LM pilot. It's unlikely that this will be the case the next time around, when we go to the Moon, not for a science picnic, but to start (hopefully) a settlement.

We'll probably even have ready a name for the host

site, our new neighborhood, as distinct from the name of the outpost itself, e.g. Pioneer Flats, Artemis Beach, New World Plain, Dawn Valley, etc. Perhaps some of the names will reflect who donated how much cash to the project.

The important thing to remember is that *no matter how much individual pioneers and scouts may care*, without a pre-agreed-upon and then religiously pursued game of site management, chaos will inexorably insert itself. Once allowed a chance to rule, chaos takes on a powerful life of its own. Witness McMurdo Sound in Antarctica, before Greenpeace photographers shamed us before ourselves and all the world. Compare cities that have grown up with a reference master plan and those (Third World villages-become-infrastructure-less-megacities, and, to be fair, many a European medieval city as well) that suddenly mushroomed like cancerous weed patches.

Basic Principles

An outpost is more than an architectural complex that we are going to put there, snap its picture, and then leave as a monument. It is presumably a nucleus from which long term “operations” will flow. These operations will impact the site. We need to give as much thought to fitting operations to site as we do to the design of the bent metal of the outpost itself.

At the same time, it would be naive to assume we can accurately pre-glimpse the full range of activities that will characterize our lunar presence down the road, as base becomes outpost and outpost becomes village and village becomes a settlement town. Our site management philosophy and game plan must necessarily be amendable. What we need is some-thing to start from, a handbook of “how not to paint ourselves into a corner”. And that is not that tall an order.

Perhaps others will have something to add to this recipe for a lunar beachhead site management masterplan, but at least a first stab at it would seem to indicate we need to make room for the following: (a) terrain to be left relatively undisturbed, for scenic and esthetic reasons; (b) roadway approach corridors; (c) sites for auxiliary equipment: electric power generation, heat rejection radiators, communications equipment, spaceport, garaging of vehicles, etc.; (d) storage and warehousing of surplus equipment, wastes and potentially recyclable trash, cannibalizable packing & shipping materials; (e) areas where the regolith can be “mined” for useful elements; (f) initial industrial park setaside; last but not least, (g) vectors for expansion of the residential and other structural parts of the outpost itself.

As/if our presence expands by orders of magnitude, the site plan for the perimeter of the base will have to give way to newer plans that embrace ever larger and larger peri-pher-al areas. No problem - if the original plan has good genes.

Esthetic Zoning Protocols

While many a technician or scientist or engineer lucky enough to be part of the original short term crews may not care, the morale both of those who will come for longer stays, and of *the millions of supporters at home who will per over their shoulders electronically*, vistas out the windows of the outpost observation domes (or whatever) ought to show both human (thoughtfully) transformed areas as well as broad expanses of “magnificent desolation” that are minimally disturbed (or

restored). In planning the site, we need to be aware of what areas are in sight from outpost “windows” and what areas will be within the horizons of those coming and going between spaceport and outpost. We need to know which areas of high ground will be broadly visible, as well as which areas will be hidden from view of the window ports of either outpost or spaceport coach. Some of this can hopefully be left in its undisturbed state, visitable from sinter-paved walks or trails. Other parts of the perimeter, necessarily disturbed in the base erection and deployment process, or in base expansion, can be “restored”, regraded and raked. Additional handsome areas can be Japanese style sand and rock gardens, or sculpture gardens - the start of uniquely lunan urban/rural “landscaping”.

Scenic “easements” cannot be left for afterthought, even in latter expansion of the site. Making provision for them will not make setting up our base or outpost any more expensive. It will simply require a bit of timely patience.

As mining operations begin, the availability of large volumes of tailings for the creation of man-made hillocks or embankments to shield storage and equipment areas from casual view will create new options. That we are fairly certain such activities and opportunities will develop, we can take the availability of tailings into consideration in devising the scenic provisions and easements of our overall site plan and its subsequent revision as the base-to-settlement unfolds itself.

Thus we will have both natural and human-landscaped areas. For either, the availability of cleared boulders, shards and other debris becomes so many opportunities for the lunan landscape architect.

Lunar “parklands” and scenic preserves need to be part of every expansion of the radius of operations. With such a philosophy, travelers, visitors, and vacationers will never need to be assaulted with the ugly exposed entrails of our industrializing impact on our adoptive new home world.

Storage and warehousing areas, mining and industrial can be out of sight behind scarps, crater walls, ridges (natural or manmade), hills, berms, in lava tubes, under ramada sheds, etc. The same goes power generation, heat rejection, and other necessary systems, *unless architecturally complementary* to the moonscape. After all, we *will need to be visually reassured* of the presence of both the technical and biospheric support ecosystems for maintenance of our presence on this, of itself, alien world. We need to see both the undisturbed beauty, and evidence that we are supported in our needs. The point is that the latter need not be presented chaotically and in disordered fashion. A basic set of esthetic zoning protocols will do the trick. The up-front cost will be minimal. Down the road, such foresight may become a definite economic plus.

The idea of **lunar “landscaping”** should be taken seriously by Earthside supporters with ready creative instincts and experience. We can’t go around planting “evergreens” or other trees, bushes, and flower beds. But *we can do something analogous*, assist in the “blooming” of the lunar soil, by bringing into being various human-midwived extrusions of surface materials. This is not so unlike what Nature does as it brings out various life-midwived extrusions of the geological elements on our own planet.

With mining tailings and other material leftover from

road grading, cutting passes through ridges or crater walls etc. it will not be impossible to create what until now have only been fantasy mountainscapes of craggy peaks etc. In lieu of flower beds, we can boulevard or “tree-line” our main settlement approaches with crystal glass snowflakes, ceramic stalagmites, and other roadside sculptures meant to be panned in passing. Roads can also be curbed with split and possibly polished breccias and other lunar “rocks” displaced in the grading process. Nor are we stuck with a palette of grays. We can whitewash with lime (Calcium Oxide) or with Titanium Dioxide, even Aluminum Oxide. We can collect the iron-rich orange soil found first at Shorty Crater, and more recently all over the place by Clementine, and use it in concentrated form to give areas various tints from rust to orange to cantaloupe. And a sprinkling of sulfur could provide a yellow.

Sculpture forests can be planned so that they take on whole new aspects as the Sun slowly marches across the lunar dayspan skies. Trees? Why we have already made trees of aluminum and aluminum foil for Christmas time. Why not sculpture “trees” which are outgrowths not of life, but of the inner potential of aluminum, iron, magnesium, and glass? They could be made stiff and immutable, but why not also with fairy gossamer “leafage” to flutter in the “breeze” of changing sunlight angles and mutual shading interference. “Trees” and “bushes” can be modular in construction using controlled “natural” randomization to vary size and branching patterns and nature-like deviations from symmetry. They could be laden with glass prism fruit to cast an everchanging pattern of rainbow colors. Let your imagination soar. This won’t happen all at once, but give it time!

At night, UV and Neon lighting will eventually be lunar supportable options. Even passive electrofluorescent lighting, driven by the sun angle and or occasional solar flares - to give an ever changing ambiance - is a possibility.

Road embankments can be dressed with cast basalt or ceramic tiles with various textures and designs. “Pebbledash” panels are also a simple option.

In short the resources of the future lunar “landscaper” know few bounds. *The point* is leaving thoughtfully saved zones and sectors for him or her to give creative expression.

Other Zoning Protocols

Last month, in our article on “Dust Control!” [MMM #89 pp. 5-6] we discussed the wisdom of sintering (lightly fusing the surface grains to a load-appropriate depth) aprons around airlocks, and of sinter-paving areas of regular traffic (roads) and areas of regular, routine activity such as areas where exterior systems are placed, or exposed or sheltered “lee” space storage areas for items needed on a frequent basis - the purpose being simply dust control. This can be guaranteed by carefully drawn up zoning protocols and guidelines.

Storage and Warehousing Protocols

We will discuss this topic at length in the article that follows. The old adage, “a place for everything and everything in its place” is the guiding philosophy we must devotedly pursue *if we are to keep chaos at bay*. Do not provide each category with a storage place of its own and voila, you have instant unrecoverable disaster, a good example of which is the Manifesto office where this is being written..

Growth Vectors - the Site Plan

While surely we will add new modules to the original outpost complex, it is unlikely that, as we move from outpost to pre-settlement village, and then on to settlement town, that we will just keep adding on. We may want to identify areas of the surrounding Moonscape for starting afresh, for example, once we are able to use made on site building materials to take care of the bulk of our expansion needs. In time the original imported outpost transplanted from factories on Earth may be decommissioned and transferred to other uses: a spartan 'hotel' for early visitors, or preserved "as is" as an "historic park".

Any new "village" or "town" needs to have a plan for expanding residential, agricultural, commercial, industrial, service, educational, administrative and other zones, properly separated, properly intertwined and interspersed, neighborhood after neighborhood, as we grow. We certainly do not need to set out from Earth with such a City Plan already brainstormed in detail. We simply need to be armed with a plenary set of principles, if even in library form.

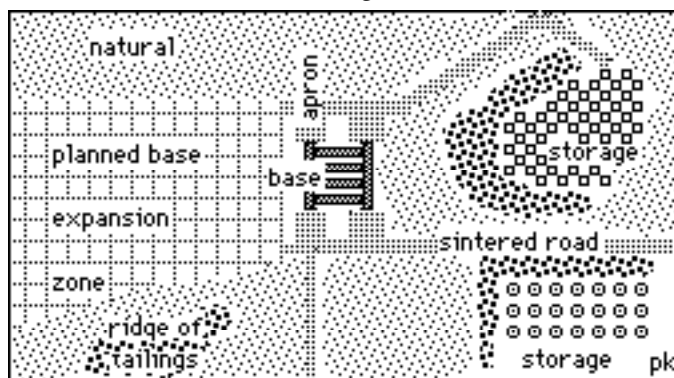
Exclave Concessions

We should not think of the Moonbase Site as encompassing a single contiguous area of set radius from our starter outpost. Depending on the legal regime(s) that may apply, our "concession" or "charter" may designate a fairly generous radius, more and more of which we will occupy and transform as time goes on.

But if we are to move in the direction of providing for an ever larger portion of our material needs as well as export potential through the use of resources indigenous to the Moon, then we may want/need to range further afield to access special deposits of minerals not found within the original site radius.

If we pick a "coastal" site, astride a boundary between highland and mare terrain, this will give us immediate access to the two major regolith soil groups. But we will still need to have access to KREEP (potassium, rare earth elements, and phosphorus) deposits such as those represented in the splash-out from the formation of the Mare Imbrium (Sea of Rains) basin over three billion years ago. Central peaks of larger craters represent a fourth suite of minerals. And then we may find Sudbury like astroblemes rich in asteroid-impact-donated lodes of iron, nickel, and more importantly, copper.

Thus we will need to set up "Exclave Concessions" as well and provide and maintain traffic corridors to such out- sources as well as to other destinations like additional (rival or secondary supportive or dependent) outposts and settlements. Each will need its own Site Management Plan. MMM



MARE housing

Avoiding chaos takes a strategic masterplan

by Peter Kokh

Relevant Reading from MMM back issues:

[Republished in MMM Classics #3]

MMM # 23 MAR '89, pp. 5-6 "TAILINGS"

[Republished in MMM Classics #4]

MMM # 32 FEB '90, pp. 5-6 "Port Nimby"

MMM # 34 APR '90, pp. 5-6 "The Fourth 'R'"

MMM # 37 JUL '90, p 3 "RAMADAS"

MMM # 38 SEP '90, p 4 "PRIMAGE"

MMM # 40 NOV '90, p 4 "Cloacal vs. Tritreme Plumbing"

[Republished in MMM Classics #6]

MMM # 55 MAY '92, p 8 "SHANTYTOWN"

[Republished in MMM Classics #7]

MMM # 65 MAY '93, p 8 "STOWAWAY IMPORTS"

Inbound Storage

From the very outset, in the first days when the lunar outpost is little more than a very elite group home, it will make rewarding sense to have in place a system of keeping track of everything. Pressurized storage space will be at a premium, woefully inadequate. It will be necessary even from day one to begin using the seemingly endless outvac as closet, attic, basement, shed, garage, and warehouse.

There will be stuff coming in from Earth, hopefully faster than it can be used — reserves. Reserve hydrogen, nitrogen, and carbon (possibly in the easier to store form of methane, CH₄, and ammonia, NH₃). Other volatiles and industrial reagents where necessary in the various processing operations. Volatiles, gasses and liquids, will be stored in tanks, and the beachhead site will sport a growing "tank farm" from the first or second landing onwards.

There will be co-imports: packing / crating materials, hopefully strategically made from cannibalizable materials that will become essential as lunar industry gets started in earnest and begins diversifying: copper and brass; stainless steel; polyethylene and polyurethane and other easy to remold polymer materials. ("Stowaway Imports", Back Issues reference above).

There will be equipment, lots of it. Capital machinery to carry on early mining, materials processing, manufacturing and fabrication operations; equipment needed to set up electric power generation and thermal equilibrium maintenance; equipment needed for recycling wastes.

Many an item on ship manifests will need at least temporary storage outside. Where? First, of course, there will be an off-loading area at the humble spaceport. From there, it will be logical to move items to staging areas near where they will be used in industry, agriculture, construction, etc.

Byproduct Storage

The next broad classification of items needing storage will be that of byproducts of human activities on the Moon. Mining and processing operations will produce veritable mountains of "tailings". As these may be enriched sources of yet other elements, not yet processed, it make strategic sense not to lump all tailings together but keep separate those from

each separate type of processing and ore beneficiation operation. Those tailings not especially enriched in anything, can, along with regolith moving surplus loads be used in landscaping operations as suggested above.

Manufacturing byproducts and quality control rejects should be carefully sorted each kind from the rest, against the day when they will become valuable feedstocks for industrial processes and entrepreneurial endeavors not yet begun, even not yet imagined.

Canisters of human fecal wastes can be stored in permashade where they will remain frozen and inert, against the day when they may be an invaluable source of fertilizer in food production and agriculture in general. Prior to storage, these wastes could spend some time in quartz covered trays in full dayspan sunlight, allowing solar ultraviolet to sterilize them thoroughly and effectively.

Finally, "miscellaneous" garbage and trash need to be stored in sorted form according to the nature of their primary and secondary recyclable content. If there has to be some residual Miscellaneous Storage Area, a catch all for everything we cannot yet see a need for, then, nonetheless, each item needs description, qualification, and recording. As a master computer program senses a building accumulation of a particular type of material or stuff not yet separately stored, a new distinct storage area can be set aside, and we will know just where to get everything that can be moved thereto.

How? We use the Double Entry Barcoding Inventory system devised for Mir by John Voigt of Lakeshore Computers in Cleveland, WI. Each item is given a barcode, as is each storage location. As an item is stored, its barcode and that of its location are read as a pair. Nothing ever gets lost anymore.

Production inventory — Items awaiting export

Early export products will include liquid lunar oxygen, LOX or LUNOX for short, and possibly other fuels such as Silane, SiH4, both mainly for rocket fuel. These can be stored in the tank farms. If we practice "primage" (every time we move regolith, in road building or construction we heat the soil to extract the precious volatiles), we will begin accumulating gasses that may be useful someday: hydrogen, carbon, and nitrogen; garden variety helium and helium-3; neon, argon, krypton, and xenon. Someday these gasses will be the feedstocks of new industries, the springboard for a second wave of lunar industrialization and diversification. If need be, the primage extract can be stored as an undifferentiated brew, leaving separation of the various gasses for a later effort.

Maintaining Quality of Stored Product

It may be wise to protect some of these stored materials under ramadas or shed-canopies, to protect them, not from the vacuum, but from attack from the lunar skies: UV. cosmic rays and solar flares, micrometeorites, and bi-monthly shock of alternating thermal extremes. Periodic tests should show if any degradation is operating, and accordingly if some items should be depreciated with storage age. Conversely, economic conditions and new entrepreneurial, industrial, and export opportunities, as well as import difficulties could work to appreciate the value of many items.

Some stores we may want out of sight. Yet an orderly storage yard in full sight, as an eloquent testimony of thought-

ful self-providence, may be very reassuring. In contrast, the sight of a storage area in helter skelter chaos would be rather disquieting, let alone an eyesore. The yardmaster's job will be important. It is a job that must be filled, filled with the best.

A Lavatube - the ultimate warehouse

Lavatubes, of whose existence we are confident from indirect evidence (rilles with natural bridges, strings of rimless collapse pits, analogy from terrestrial shield volcanoes made of similarly non-viscous lava), and whose likely scale and size dwarfs known Earthside analogs, present themselves as ideal warehouses. They keep everything out of sight and out of harms way from the celestial elements.

They may not be used for that capacity right away, however, because it would seem that access could present some initially discouraging obstacles. We may need to either erect industrial elevators or grade negotiable access ramps down rough and rugged talus slopes from cave-in entrances. Yet certainly, their great volume and its weather free character will guarantee their use for storage as soon as they can be found and access provided.

"A place for everything, and everything in its place." It's not just for closets and desks anymore! It's a philosophy that will bode well for our future on the Moon, if we abide by it, providing an eventual industrial and entrepreneurial bonanza. Equally it is a philosophy which will spell out our sentence, if we give it but lip service. We can look at it as a sort of "Real Accounts" ledgers, in which we are dealing with real items, not just financial values.

Again, the operative condition is that we start such housekeeping practices from day one, for, as we have warned, chaos, once it has its foot in the door, takes on a life of its own, setting up conditions from which it will be extremely difficult to recover.



by Peter Kokh

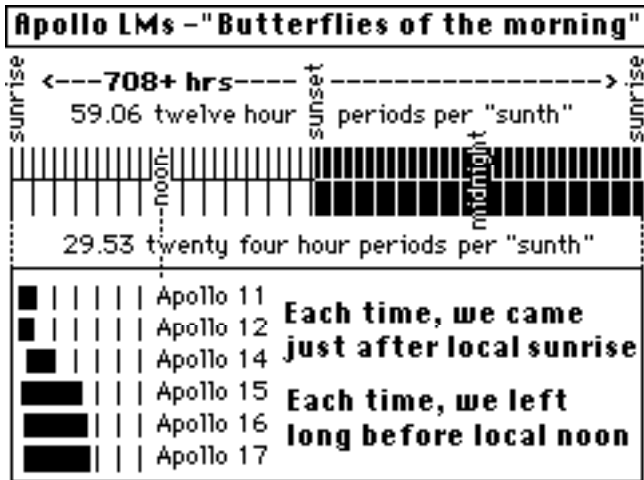
Dawn Touchdowns, Pre-noon Lift-offs

For sake of best long-shadow lighting conditions as well as heat management, All the Apollo missions landed shortly after local sunrise, and as if subconsciously frightened senseless of nightfall, left well before local noon. We haven't come close to experiencing a whole lunar dayspan/nightspace cycle! Here are the figures for each mission.

- A11 TD 10.93 hrs after local sunrise
LO after 21.60 hrs after local sunrise
(like 6:22-7:06 am on Earth with 6:00 am sunrise)
- A12 TD 10.12 hrs after local sunrise
LO after 19.52 after local sunrise
(like 6:21-7:01 am on Earth with 6:00 am sunrise)

- A14 TD 20.75 hrs after local sunrise
LO after 33.51 after local sunrise
(like 6:42-7:50 am on Earth with 6:00 am sunrise)
- A15 TD 14.04 hrs after local sunrise
LO after 68.91 after local sunrise
(like 6:29-8:49 am on Earth with 6:00 am sunrise)
- A16 TD 17.82 hrs after local sunrise
LO after 71.04 after local sunrise
(like 6:36-9:00 am on Earth with 6:00 am sunrise)
- A17 TD 16.8 hrs after local sunrise
LO after 75.00 after local sunrise
(like 6:34-9:06 am on Earth with 6:00 am sunrise)

NOTE: Lunar Sunrise to Sunset is 354.367 hrs = 14.7653 days
Full Sunth (local day) is 708.734 hrs = 29.5306 days



This is a pattern similar to early sorties to Antarctica. There, we came after the spring pack-ice break-up and left well before the fall freeze-up - *for the first two decades*. It wasn't until Byrd set up Little America in 1929 [a site abandoned 30 years later in '59 as U.S. Antarctic operations concentrated on McMurdo Sound] that we took the plunge and "overwintered". That was quite some hurdle, mentally and emotionally, as well as operationally and logistically. Now we face the same hurdle on the Moon. But until we do it, all our talk of "permanent presence" is just so much empty macho bravado.

In the case of Little America, the major hurdles to be overcome were the need to build up during the summer months enough fuel (heat, power, and vehicles) and food reserves to last the long cold winter night months when resupply would be impossible. Rescue would also be impossible, meaning medical supplies and kits had to be more adequate, and medical personnel more fully trained. On the Moon the challenge will be similar although the nightspan is only a twelfth as long.

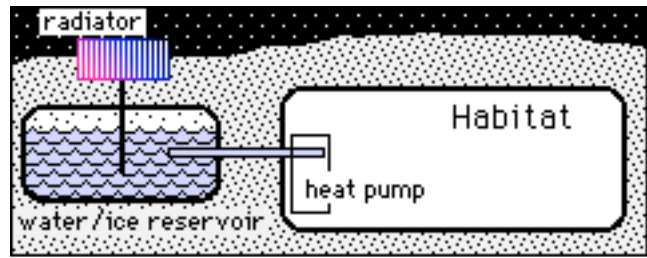
Thermal management

Surface temperatures drop drastically and quickly after lunar sunset. But, *these are surface effects only*. The powdery soil is a poor conductor, and a poor reservoir, of either heat or cold. A couple of meters down, below the blanket of shielding soil, temperatures remain about -4° F or -20° C all the time.

Most expect a heat buildup within the buried habitat, heat from living, heat from operations, that will not be drawn off by the surrounding soil as fast as it is generated - even at night. If an equation of heat inputs and losses shows a net heat

rise even during nightspan, a system of external heat-shedding radiators will be necessary.

If, however, because available power during nightspan means powered down operations, and if that in turn means a thermal deficit during nightspan, then some sort of thermal heat sink accessed by a heat pump might not be a bad idea. We'll have, or should have, the former - in the form of water reserves. A large reserve tank can be buried in the soil not far from the habitat. Heat from the water would be pumped into the habitat by nightspan, the direction reversed for dayspan cooling. A net heat excess over the whole dayspan/nightspan cycle would then be shed by external radiators.



If we don't bring along, find, or generate (i.e. adding hydrogen to locally produced oxygen, probably in fuel cells to produce night power and water both), enough water to make such a heat-pump accessible water reservoir work, then our plans to make our presence "permanent" are in big trouble.

Successful thermal management will depend largely on how much care is taken to isolate major heat-producing activities from the habitat areas. This means automated unpressurized processing and manufacturing plants, saving low temperature aspects of production (finishing, assembly, etc.) for occupied areas.

Nightspan Power

Many suggest solving the nightspan power problem by bringing along a small nuclear power unit. Even if the legal and political hurdles can be overcome (e.g. by having the Russians contribute this system), the point is missed. *No matter how big the nuke*, there will still be less power available during nightspan than during dayspan for the simple reason that during the latter, *the Sun also shines*, its heat ready to do work - simply and cheaply.

The Sun can provide nightspan power in these ways:

- a. Solar heat can be used via several processes to produce oxygen from moon rock by dayspan. During night-span this oxygen is combined with hydrogen brought from Earth, in fuel cells, to produce power - with pure potable water as the byproduct.
- b. If necessary, solar power can also be used during dayspan to electrolyze a portion of the water reserves back into hydrogen and oxygen for nightspan fuel cell fuel. (In addition, the Sun's raw ultra-violet rays can help purify the remaining water reserves under cover of UV-transparent quartz.)
- c. If there is an early cast basalt industry to provide paving blocks and other low performance items useful to the expanding base, possibly as a sideline to oxygen production through heating the moon rock, this would open another road for Sun and water to work synergistically to provide

nightspan power. If during dayspan, when the solar concentrators power these industries, there builds up an excess residual pool of molten rock and this is kept shielded from the heat-sucking night sky in an underground reservoir, the residual heat of this “magma pool” can be tapped to produce steam to run the base’s nightspan generators. This is the idea of LUNAX director David Dunlop. A refractory lining of aluminum oxide would make such a magma-pool reservoir more efficient, but might not be absolutely necessary.

Mark Reiff of General Space Corporation suggests another form of lunar heat pump. If vibro-acoustic testing locates a relatively small underground void (cavern) near the surface (less than 100 feet), this can be accessed by drilling. The natural reservoir can then be filled with a thermally conductive material (he suggests smelting regolith into molten aluminum). The thermal properties of the available material should drive the purity requirements. The material would be allowed to reach an equilibrium (cool). Next you would set up a thermal dynamic generator (Sterling cycle would work good) with your heat source on one end and the newly created heat sink connected to the other. You could shade the generator and the top of the heat sink to even provide power by dayspan too. [Smelting aluminum, however, is not likely to be an early outpost technology - Ed.]

The Sun and Water, then, seem to be the simple and elegant basic ingredients for a nightspan power system (as well as maintaining thermal equilibrium). Elaborate and expensive plans for providing nightspan power (or maintaining thermal equilibrium) by other higher tech means seem foolish.

The division of labor into hot in-vacuum and cool in-habitat chores (see above) in order to assist in thermal management will also work neatly to separate man-hours into energy-intensive dayspan aspects and labor-intensive nightspan aspects of the total production and operations cycles.

I have suggested that this fortnightly change of pace will become a well-liked feature of lunar life. Some have seen it as a burden to be avoided. Do not forget that on the Moon there are no seasons, no daily changes of weather, both of which add spice and interest and renewal to living on Earth. If this nightspan power “deficit” were ever to be effectively eliminated, the biggest source of rhythm and change of pace would be gone with it. *Productivity gains would be temporary as morale slowly plummeted from routine, boredom, ennui.*

Other nightspan power solutions frequently proposed are well down the road, something for later generation advanced settlements to consider. These include solar power satellites, lunar solar array networks (one over the nearest pole makes the most sense as it would be in sunlight whenever the outpost is experiencing nightspan), helium-3 fusion plants, and, oh yes, lunar hydroelectric [see * below].

Air/water/waste management

Overnighting will also require much more capable recycling systems than did missions only intended to spend a couple of days on the morning Sun lit surface. Some water recycling chores can be solar-operated, as suggested above. By nightspan, used water could simply accumulate; or, freezing (by sky exposure) could work to separate out some impurities.

Human solid wastes could be stored out-vac, left to freeze in shaded sanitary containers. Rather than be a problem for eventual disposal, such compostable organics-rich material will become a banked resource of great value for the eventual commencement of regolith-soil based agriculture, once creation of significantly cheaper pressurized expansion volume becomes possible using on site produced building materials.

Other “Overnighting” Needs

Plan as we will to stock up by dayspan for a dayspan-only logistics operation of resupply and manpower relief from Earth, we will be prudent to allow for the possibility of night landings and launches. Once we can land on a dime using signal clues rather than visual ones, this should be no big deal. It does mean, however, that the outpost’s “spaceport” be more than a simple designated circle in the sand. It will need to be equipped with beacons and lights and radio.

For this and who knows how many other contingencies, a service vehicle that can operate at night is also a must. This means more than headlights. It means power supplies, motive systems, and lubricants that can withstand temperatures of -200° F or -130° C with no problem.

Overnighting Measures, a Test of Outpost Design

Any approach to lunar outpost design, NASA/International or commercial, in which *every aspect* does not reflect the needs of “overnighting” begs to fail. If you are honest, you will realize that some of the above capacities are not self-obvious *if you conveniently ignore the fact that* some time after your base setup landing, *the Sun will set*, and stay set for almost fifteen days, over and over again every sunth, forever.

Relevant Readings from MMM back issues

[Republished in MMM Classics #1]
MMM # 7, JUL ‘87, “POWERCO”

[Republished in MMM Classics #4]
MMM # 31, DEC ‘89, pp. 3-5, “Ventures of the Rille People” (Princeton design study report), V.

* Multiple Energy Sources.

[Republished in MMM Classics #5]
MMM # 43, MAR ‘91, pp. 4-5. “NIGHTSPAN”

*If it isn't difficult
it's probably
not worth doing!*

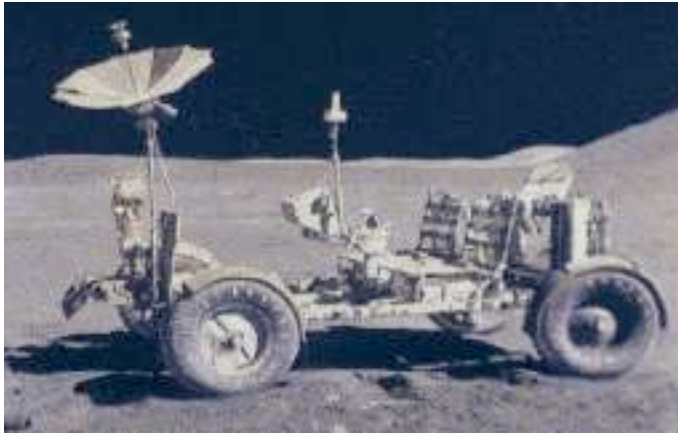
*Opportunity never comes
to the one who waits for it*

Carpe Diem! (CAR pay DEE ehm)

Latin Proverb *Seize the Day!*

Revisiting the MOON BUGGY

Would lunar rovers left on the Moon still be in working condition when we return?



by Bryce Walden, Oregon Moonbase (bwalden@aol.com)
[response to a screenwriter's question on America OnLine]
[reprinted in MMM with permission]

General contractor for the Lunar Roving Vehicle (LRV) was Boeing; GM Delco made the electronics. The LRV was first used on Apollo 15 at Hadley Rille, and in all subsequent missions. The chassis was aluminum. The essential "buggy" massed 400-600 lbsm (pounds-mass) (180-270 kilograms) depending on equipment. It could carry equipment, astronauts, and payload up to 1100 lbsm (499 kilograms), more than twice its own weight. Yet it was not strong enough to hold the astronauts on Earth.

Top speed mentioned by my source was 14 kph (8.7 mph); the speedometer was calibrated 0-20 kph (0-12.4 mph). Average speed on all three missions using the LRV was 5.17 mph (8.3 kph). Average for Apollo 17 was 5.0 mph (8.0 kph), total distance traveled was 22.3 miles (35.9 kilometers), and total time driving was 4:26 hours.

Power was supplied by 2 silver-zinc batteries, each 36v, 121 amp-hours per battery, encased in magnesium, then enclosed by thermal blankets and dust covers. Each battery had a relief valve for protection against excessive internal pressure. Thermal control was critical: the batteries had to be maintained between 40° F (4° Celsius) and 125° F (52° Celsius). The only practical method of heat rejection in the vacuum was by thermal radiation. Unfortunately, the slightest amount of lunar dust on the radiators (essentially mirrors) would "effectively destroy" their ability to perform. For this reason the radiators were kept closed during activities, to be opened manually by astronauts after "parking" for the "night." "During operation, heat generated was stored in heat sinks consisting of two LRV batteries and tanks containing wax-like phase change material." According to Gene Cernan and Jack Schmitt, "If you take a couple more batteries up there, that thing would just keep going...."

However, these guys aren't Moon Buggy Mechanics. Other astronauts have been known to say the buggy had used

up all warranties by the end of the mission (5 days or 250,000 miles....). Besides the batteries, the flexible spline inside each wheel hub, part of the kinetic power transmission system, may have degraded. Countless thermal cycles of the vehicle between lunar day (+250° F, 121° Celsius) and lunar night (-0° F, -157° Celsius) will take their toll on structural elements, electronics, and other system parts. There is also the possibility of radiation damage to the control electronics. Of course, it *might* work, for a little while --perhaps a heroic last gasp. With fresh batteries, of course. That overpressure release probably let vital elements escape as the batteries heated to lunar daytime temperatures.

One other interesting note is that the LRV had an inertial navigation device that always pointed toward the LEM (bearing and distance), so the astronauts would not have to guess, in the austere and misleading lunar environment (ever taken a walk in the desert?), the quickest way back to the base. They also did not have to stay in sight of the LEM.

Lunar rover data and quotes are from "The Lunar Roving Vehicle: A Historical Perspective" by Saverio F. Morea, Director, Research and Technology Office, NASA Marshall Space Flight Center, Alabama, where the LRV was tested. The paper was presented at the second Lunar Bases and Space Activities of the 21st Century conference, April 5-7 1988, Houston TX. Contribution No. LBS-88-203.

That being said, I don't think we should depend on or plan to use any of the one-shot equipment sent up with Apollo. I prefer the idea of fencing it off and preserving these first explorations as well as possible. We should be sensitive to other sites of interest, as well. **BW**

Mail Box



Unmentioned advantage of shelter hangars

10/2/'95. One advantage of sheds or hangars as described in your recent article, "Shelter on the Moon" [MMM # 88, page 4] is that they would seem ideal for inflatables. Think of it.

- no thermal stress;
- no exposure to UV or cosmic rays
- no exposure to solar flares
- no exposure to micrometeorites
- no shielding emplacement pressure surges or trauma dangers
- lee environment for deployment
- EZ maintenance and access to exterior surfaces of inflatables

The only problem I see for not-directly-shielded inflatables is a slow buildup of corrosive atomic oxygen; but this seems unlikely in a "lee" environment.

Thomas Heidel,
Milwaukee, WI

*From now on, we live in a world
where men have walked on the Moon.*

And it wasn't a miracle!

We just decided we wanted to go.

Jim Lovell, in "Apollo 13"

The "Tanstaaf!" Editorial

"There ain't no such thing as a free lunch!"

Common Lunan settler exclamation from

"The Moon is a Harsh Mistress" By. Robert A. Heinlein

Growing "the Chapter Product"

Basic Assumptions

Every chapter is different. Unavoidably, each reflects the talents, interests, and priorities of its most *driven* officers. But perhaps this is not how it should be. Let's ask the pointed question: should the chapter be a "narrow tent" or a wide one?

Clearly some voices clamor for a restrictive read:

"A Space Activist is one who works to move the political establishment to a more aggressive public space program."

Happily, that has in recent years been largely amended to include agitation for legislation more favorable to private sector space activity. Even so corrected, the definition is horse-blinded, self-crippling, fundamentalist, dogmatic, paramilitary hogwash.

Narrow Tent vs. Wide Tent Definitions:

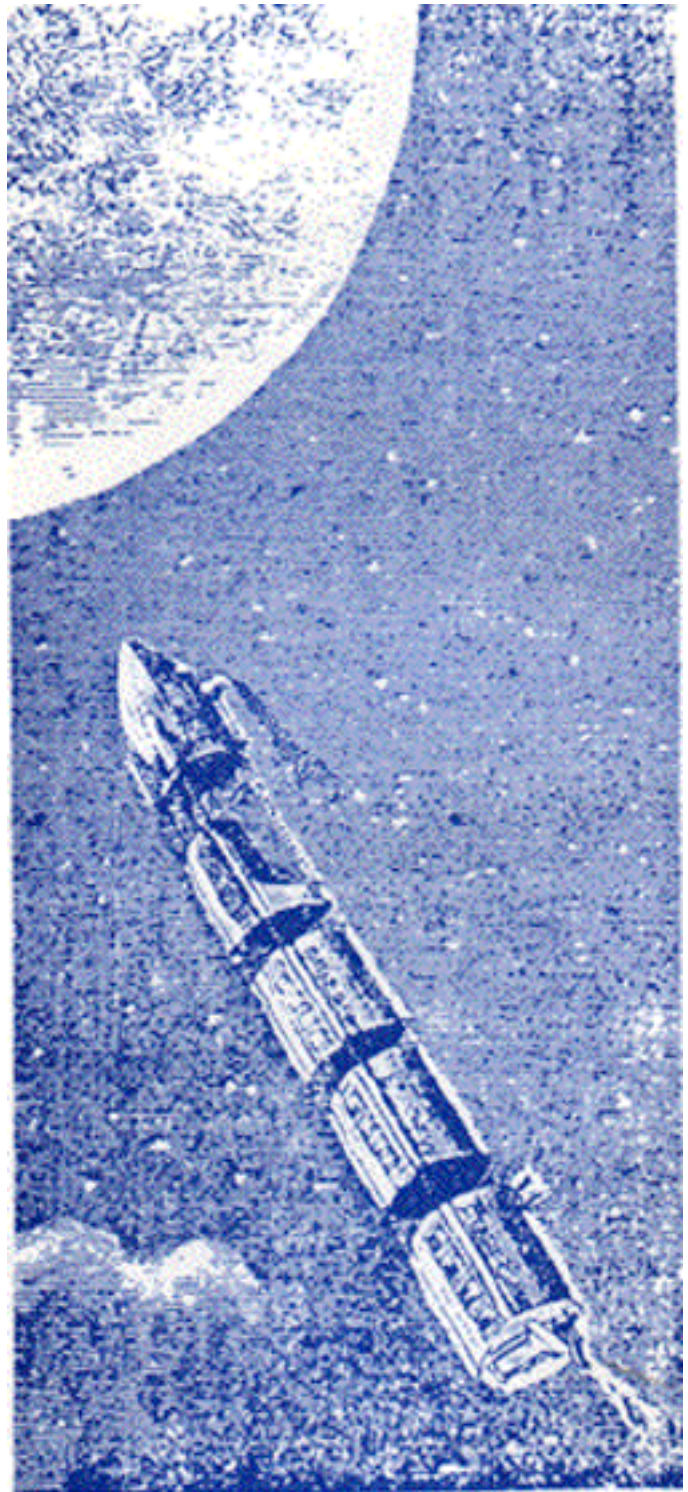
Even in cases where the chapter inspirators have another agenda, such as public outreach, the monocular "Narrow Tent mentality" works inexorably to restrict the Chapter Product to express the talents and interests of those taking charge.

Yet each chapter surely has members whose personal approaches would differ, whose interests and talents are better applied to projects not even thought of by the chapter leaders. It is high time we all adopt a "Wide Tent definition."

"A Space Activist is anyone who exercises his or her own talents, whatever they may be, to advance the cause of the realization of an open space frontier:"

Adopt such a definition and the door is *unlocked* to a whole slew of projects, even be they one-person endeavors undertaken *under the aegis or umbrella of the chapter*. Why not? What bible says every chapter project has to be a Team Project, much less a project undertaken by all (read 'anyone uninterested should stay home')? It is time to respect our individual chapter members and grow the Chapter Product to reflect their interests and talents and aptitudes and agendas.

To do this, we must get to know much more about each of our chapter members. **PK**



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