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

Moon Miners' Manifesto

www.MMM-MoonMinersManifesto.com

MMM Classic Themes

Lunar Analog Research

A List of Research Needed in Preparation to Open the Lunar Frontier and a List of Analog Station Activities are Flip Sides of the Same Coin

[So do read the Research Theme Issue First!] By Peter Kokh

The common expectation that a Lunar Analog Research Station must be set in a terrain that in some way reminds us of the Moon, may be proper so far as outdoor activities are concerned: geology prospecting in particular. But there are many types of research for which the "needed analog" is not of the lunar surface. A primary example is research that requires simulation, not of some moonscape, but of the Moon's month-long dayspan-nightspan cycle. Four things that come to mind are power generation and storage, thermal management, operations management, and agriculture.

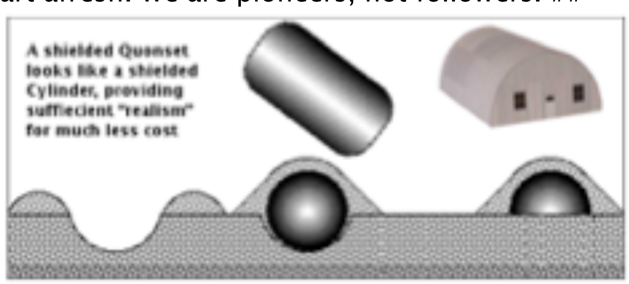
Nor do all lunar analog research experiments need to be done in one location. A one-location operation necessarily requires researchers to take turns, with a limited amount of time, and with significant logistics expenditures: getting crew and equipment to and from. A decen-tralized or polycentric plan would allow researchers to "do their thing" where they live and work, in conjunction with any associated institutions or corporations, on a year-around basis.

The Mars Society's two analog outposts, on Canada's high arctic Devon Island and in south central Utah have drawn considerable publicity for the Society. And publicity attracts members and funding. But the research that gets done, gets done inefficiently.

If a number of research programs are supported, coming online when each is ready with sufficient support - not according to some idealistic plan - there will still be plenty of opportu-nity for publicity, and local publicity can stir interest, attract funding and new members as well.

The Moon Society might consider such a decentralized plan. We may be able to start with opera-tions already underway, with the Society coming aboard as a co-sponsor, providing funding for modest but needed additional experiments, for example.

This plan will not result in the gut & glory camaraderie that exists between hundreds of veterans of FMARS/MDRS crews. We must start afresh. We are pioneers, not followers. ##



http:// www.moonsociety.org/moonbasesim

Mars Desert Research Station, Hanksville, Utah, site of Moon Society Simulation Exercise on Crew 45, Feb. 26 –March 11, 2005 Note simulated tunnel that we built between the Hab and the GreenHab.

CHRONOLOGICAL INDEX MMM THEMES: Lunar Analog Activities

NOTE: Many of these articles describe how we will live on the Moon, We selected them to show how we should design our Lunar Analog Stations to provide the right kind of atmosphere, as well as to test out and debug the technologies in question. **PK**

Not Previously Published

- The Sandbox – teleoperation experiments
- Volcanic deposits – basalt product
- Abandoned mine galleries above the water table
- Artemis Society's Project LETO Proposal Visitors Center &/or Research Station
- The role of Design Contests and Engineering
- Young People and analog research

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MMM # 201 Modular Biospherics; Living Walls
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- What a Lunar Analog Research Station Should Attempt to Demonstrate
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- The Sandbox – teleoperation experiments
- **Volcanic deposits – basalt product**
- **The role of Design Contests and Engineering**

ANALOG RESEARCH STATION LOCATIONS

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Not Previously Published

- Abandoned mine galleries above the water table
- Volcanic deposits – basalt product

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Biospherics Research Lags Behind Hardware R&D

If you read between the lines of most space scene commentaries, be they exhortations or complaints, one thing becomes clear; the writer seems to think that if only we would invest in the necessary hardware, budgeting more money for engineering research and development, we could bust the Space Frontier wide open. This is the case especially with those who would set deadlines or timetables for reaching this milestone or that one, e.g. "We ought to have a permanently occupied Moon Base by the year 2001!"

Something very vital is being forgotten. In the process, these forgetful space advocates are working unwittingly to set us up for another painful false start, å la Apollo.

To establish communities beyond Earth that are more than mere caricatures, **we will need to provide mini-biospheres** in which settlers will live within closed-cycle environ-mental life support. We still lack any work-able ideas of how to build such a system.

Arizona's Biosphere II notwithstanding, our ideas on how to set up the mini-ecosystems that will fully support our existence without being crushed by our demands upon them, are at best, so much theory. In this light, even such modest and basic projects as the Milwaukee Lunar Reclamation Society's Guidelines for Experiments in Lunar Agriculture intended to zero in on minimum Lunar nightspan lighting requirements, and other projects such as determining the most practical and timely way to turn sterile moondust into serviceable soil, are little more than cute amusements. There is so much practical biosphere know-how that we lack! And we beg to fail if we don't address that lack.

By and large, a majority of space-interested persons come from the ranks of persons excited about engineering and computing developments, technological spin-offs, and the hard sciences. This makes for a very lopsided, poorly rounded membership. This biased balance is inevitably reflected in Society policy and strategy.

It cannot be stressed enough that any spacefaring civilization must also incorporate appropriate biosphere and agriculture expertise. We could reduce launch costs to a dollar a pound, and build a NASP fleet, even a space elevator and fast nuclear rockets by the hundreds - and the Space Frontier would remain teasingly beyond our grasp, if we have not also learned how we can re-encradle ourselves in the hostile reaches beyond Cradle Earth, in which unearthly settings we propose to make ourselves equally at home.

NASA has now put CELSS (Closed Environmental Life Support System) research on hold for budget reasons. Where is the protest from space enthusiasts? We are more concerned with Shuttle-C, fair-play for also-ran entrepreneurial launch companies, and other worthy but far less critical initiatives. Dared the would-be homesteaders of our past head west solely equipped with know-how about covered wagons, telegraphy, mining, and horse-shoeing?

NSS sorely needs to broaden its recruitment pitch, and supporting literature, in an all-out effort to bring into full participation those whose backgrounds, or hobby interests, include biology, ecology, ecosystems, agriculture and gardening, even animal husbandry. The Society's excellent monthly magazine, Ad Astra, should reflect this balance correction by soliciting appropriate articles. NSS has said in the past that it foresees an open frontier in which there will be a place for people of all walks of life. That boast should be effective up-front policy, not just afterthought and window-dressing!

Many of us are impatient, blaming the government for delays in producing the hard-ware we'll need. Meanwhile, we naively assume that once the hardware is ready, everything else will fall into place without our having to trouble our collective selves about it. It is both silly and self-defeating to set time-tables and deadlines on such a deficient basis. We ought to be more concerned with making sure that all we will need is in place before we return to the Moon to stay, than with when we will do so. **PK**

MMM #41 December 1990

Introducing MMM's new Vision Statement

"Expanding the Human Economy Through Off-Planet Resources"

With the December 2010 issue of MMM, #241, this vision statement has headed each issue for twenty years. We are not going to the Moon just to explore and understand our mate-world. We are going to learn how to use its resources to help solve problems on Earth, including environmental degradation and insufficient clean energy supplies.

To do this, we must learn how to live on the Moon, using its resources to make ourselves at home. While the Mars Society will say that they also want to learn how to make Mars another human world, the vast percentage of experiments and research done at MDRS and FMARS have been to develop exploration tools and methodologies.

In that respect our goals go much further, and the number of tools and methodologies we need to develop in our analog programs is much longer. Many overlapping efforts will be needed.

MMM #50 - November 1991

Modeling a Lunar Analog Station After Proposed Hostel Structures

If we do build a lunar analog research station, for whatever kind(s) of research, it makes sense to model how we would build on the Moon itself. In the early days, before we are able to construct modules from lunar materials, the only way to provide real elbow-room will be with inflatable units, including "hybrid inflatables" with a rigid component. This will give us more volume for less shipping weight and delivery cost. By modeling suggested architectures, we will be able to identify design problems and strive to find ways to address them.

In MMM #50, we reprinted part IV of our Lunar Hostels paper delivered at ISDC 1991 in San Antonio. In this section of the paper we discuss some appropriate architectures. The full paper is available online:

http://www.moonsociety.org/publications/mmm_papers/hostels_paper1.htm

This treatment in not intended to be exhaustive by any means, but rather to be a discussion starter. We highly commend Bigelow Aerospace for their further development of NASA's discontinued TransHab inflatable technology research. But while we have the opportunity, in expanding an analog station, we ought to try some alternative architectures. Some options will be suitable for one kind of use, other options for other applications.

The text follows:

IV. POSSIBLE ARCHITECTURES APPROPRIATE FOR HOSTELS

The operative philosophy in making architectural and design choices for lunar hostels, is getting the most usable square footage per buck. Our intent is not to give an exhaustive treatment of the many possibilities by which prefabricated or built-on-site hostel shelter space can be provided. But we point out appropriate considera-tions that should affect the final choice in each particular case. We have attempted to illustrate some previously unexplored avenues.

Hostels Pre-built or Prefabricated on Earth

(1) Hard-Hulled Modules: Lunar hostels established prior to the startup of settlement industry, would be unlikely to employ lunar materials except as shielding mass. That is, it will be necessary to pre-build them on Earth. But neither ready-to-use payload bay sized space station type modules, nor structureless inflatables seem ideal for the purpose. The former quite simply offer inadequate space and if brought up to the Moon empty, will squander payload bay capacity. Multiple modules, stuffed with provisions and serving as temporary cargo holds, to be unloaded on the Moon and then interconnected, are a more reasonable possibility. But their deployment would call for an welcome load of high-risk crew EVA hours. It seems the wiser course to reserve human activities on the Moon for tasks that can be performed under shelter. The modular approach does, however, allow the hostel complex to grow with each new visit.

(2) "Telescoping" hard-hull designs are another story. Pre-built hostels of this type could be built to extend either unidirectionally or bidirectionally, with the smallest diameter section(s) being loaded with built-in features and the wider diameter telescoping sections offering simple unstructured spare volume. The inside walls of these sleeves could be furnished with electrical service runs, flush lighting, recessed attachment points, etc. Deployment would be accomplished via simple pressurization which would securely force together properly designed o-ring-fitted inner and outer flanges providing a seal with more than sufficient mechanical strength to maintain integrity under any conceivable internal traffic conditions.

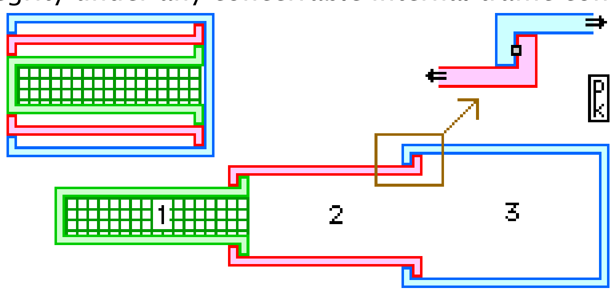


Figure 3A: Telescopic Module: The thickness of the sleeve walls, and the amount by which one is smaller than the other, is exaggerated to show detail.

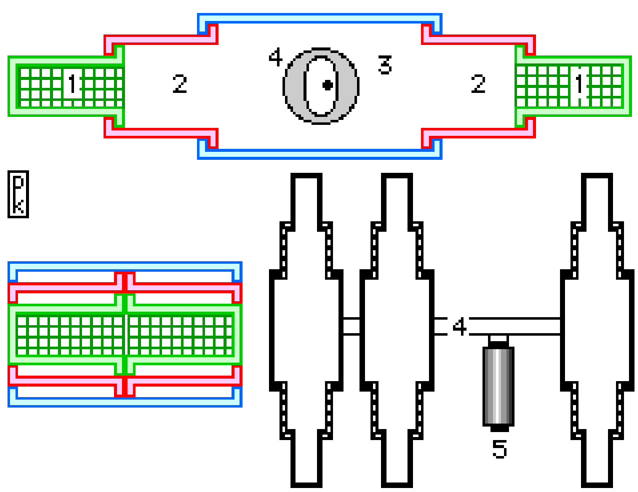


Figure 3B: Bi-telescopic Module: [4] connector tube. [5] docked frog, perhaps under a shielded canopy.

Alignment would be preserved by the simple expedient of a key/keyway feature with keys on the outer flanges and keyways on the outer surface of the inner sleeves. Outrigger skid-dollies attached to the smaller end(s) and the outer flanges of the widest diameter middle sleeve, riding freely on a pre-leveled compacted gradeway, would midwive the deployment.

Airlocks or docking ports could be placed at either end. The widest diameter sleeve could have a side-mounted protrusion.

A pair of bidirectionally expanding units could turn this constraint to advantage to conjoin "H" style. In fact, any number of such units could polymerize in like fashion. For this reason, we have dubbed the basic unit the "monomer". The beauty of this bi-telescopic design is that it allows a single payload bay to deliver perhaps two and a half times its own usable interior volume. The apparent drawback of the strongly linear floor plan (and required special attention to site preparation) becomes a potential plus through H-H hookup possibilities.

We think this telescopic approach to hard-hull modularity is much more promising than any of the more conventional segmented approaches. Indeed, such a configuration might also prove to be the eventual archi-tecture of choice for full-function lunar bases and non-gravid orbital stations as well. Single units would be especially trailerable and might thus be ideal for manufacturing in the lunar settlement for trucking to roadside locations around the Moon, where they could be deployed under previously built emergency flare sheds.

(3) Simple Inflatables come in spheres and cylinders, shapes with unstable footprints and awkward to work with if not pre-decked. In free space, the inflatable cylinder can be subdivided in radial cross sections, its caps serving as top and bottom. But on the Moon, one can only lay such an shape on its side, especially given the need for shielding. Then, as with the inflatable sphere, the inconveniently curved inside bottom surface has to be somehow decked over. Nor do pure inflatables lend themselves easily to even modest built in features and furnishings. An alternative we do not recall seeing treated, is the inflatable torus, which would seem to offer the maximum stable footprint per usable volume.

(4) "Hybrid" Inflatables were examined next. These are structures employing both hard, feature-loaded elements and soft inflatable sections.

(a) First we sketched a flat footprint "**sandwich**" model with a prefab floor section with pop-up built-ins and utilities, paired with a prefab ceiling section with built-in lighting and pull-down features, the two slab units connected by a peripheral inflatable wall. (The curvature of the walls, providing maximum volume for combined flexible and rigid surface areas, would follow the lines of a projected cylinder of the same diameter.) Collapsed for transport to the Moon, such a hybrid could offer clear flat floor space a full fifteen feet wide if designed to fit the Space Shuttle payload bay or up to 27 feet wide if designed to fit an in-line (top-mounted) shuttle derivative cargo faring. Such hybrids could be deployed with significantly less crew EVA hours, or even be tele-deployed. With more habitable volume as compared to the rigid module traveling in the same hold, the folded "sandwich" would make room for plenty of additional cargo, either by taking up less space or by weighing less.

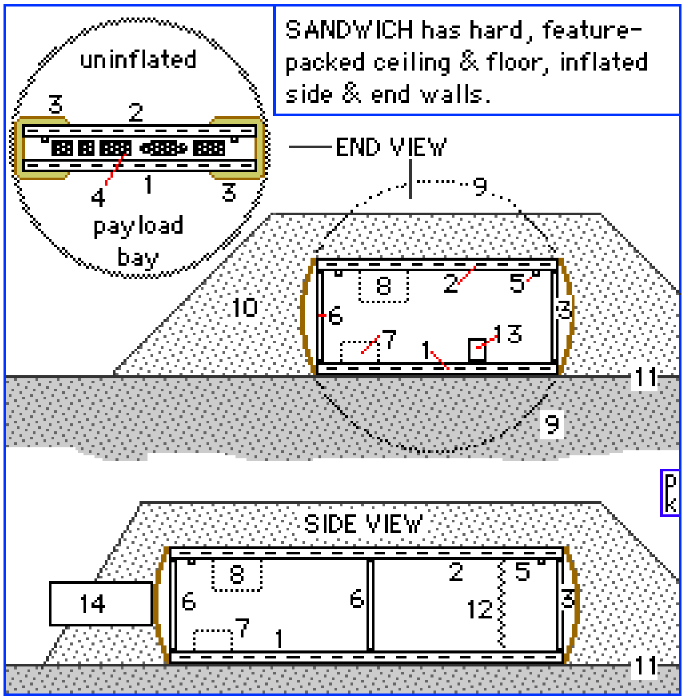


Figure 4: The Sandwich: [1] Floor module with pop-up built-ins.

[2]Ceiling module with pull-down units. [3] Inflatable sidewalls and end walls.

b) While the great advantage of the sandwich design is that it offers a stable flat footprint and a ready to use flat floor, it offers little more than half again as much space as a rigid module designed to travel in the same cargo hold. Another configuration, which we've dubbed the "slinky", features rigid feature-packed cylindrical end caps connected by a cylindrical inflatable mid-section. Here instead of multiple circular ribs and worm-like segmented lobes, we strongly suggest employing a continuous helical rib spiral as this design choice offers an elegant opportunity to build-in a continuous electrical service run along with other utility lines and lighting strips within this skeletal monorib.

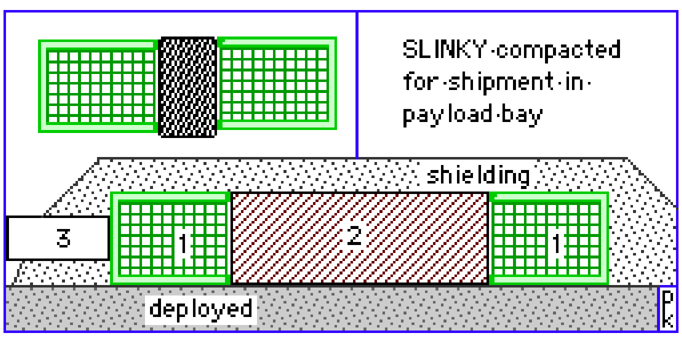


Figure 5: The Slinky: [1] Pair of rigid end caps, outfitted with build-in features and equipment. [2] expandable slinky module (unfurnished). [3] docking tunnel.

c) Next we came up with a novel wide-floored lunar "**quonset**" idea. It has a stable footprint and favorable width to height ratio. While all built-in features would have to be floor-housed pull-ups, this design offers about two and a half times as much floor space as the "sandwich" for the same payload bay space. The inflation-reinforcement of a triple slab hinged floor is a design innovation that offers opportunities for crawl-space storage, utility space, and ventilation that beg to be pursued. A telescoping vestibular passageway for vehicle coupling could be built into one or both inflatable end-walls as illustrated.

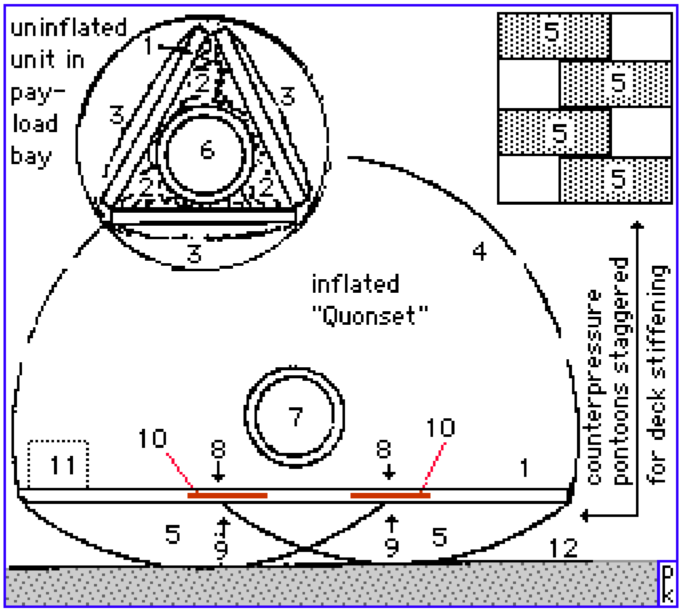


Figure 6. QUONSET:

[1] Hinged 3-section floor deck. [2] uninflated quonset roof/wall
[3] uninflated floor support pontoons [4] inflated quonset roof/wall
[5] Inflated floor support pontoons [6] In transit position of docking module
[7] Docking tunnel in end wall [8] Downward air pressure on hinges
[9] Counterbalance pressure on hinges [10] Contingency stiffening bars
[11] Representative pull-up feature [12] Ground contour before shielding

d) Finally, we've sketched a **hybrid torus design**, dubbed the "**donut**"*, with the donut-hole wall replaced with a compact payload-bay sized hexagonal "works" module loaded with pull-out built-in features including top mounted central solar, visual, and EVA access, side-wall vehicle docking port, decking erected from parts brought up in the core module's "basement', complete with a peripheral jogging track. [see illustration, below]

Taking further advantage of this design, the naked inner surface of the outer sidewall could easily be pre-painted or pre-printed with a 360o panoramic mural medley of Earthscapes, Spacescapes, and Moonscapes.

By including two additional coupling ports in the donut's outer wall at 120° angles we would make possible 'benzene ring' clusters of individual donut units for indefinite "organic molecular" expansion potential. Small conventional instrument-packed modules could be brought up from Earth and coupled at unused ports to allow endless upgrade of the facilities. Of the hybrid inflatable designs investigated, the "donut" seems to lend itself best to all our various design goals. We intend to work with this central core torus design further to bring out its full promise and tackle any unsuspected problems. [* David A. Dunlop has since rechristened this design the "**Moonbagel**"]

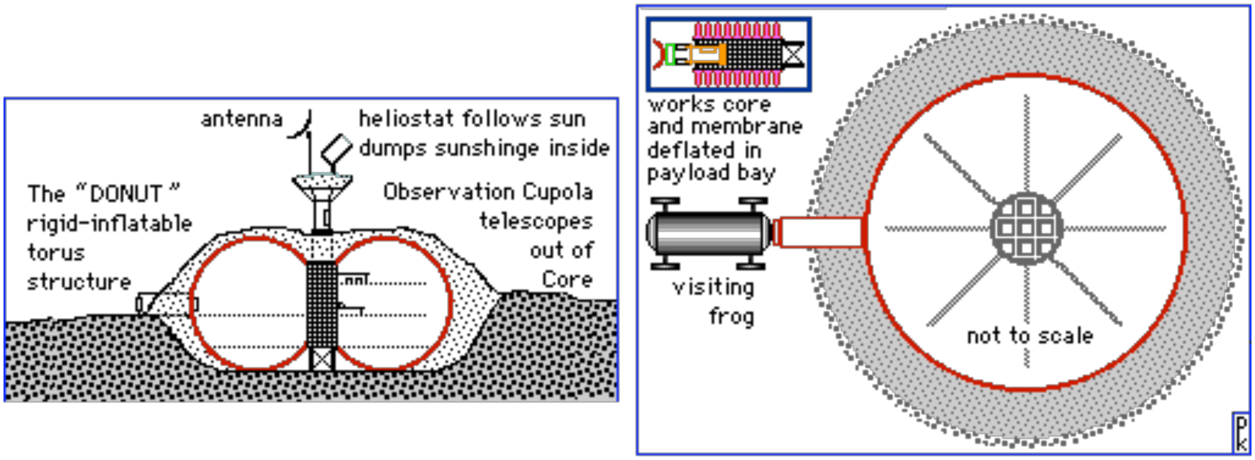


Figure 7: The Donut: This 3 floor model at top is an upgrade of the simpler design in the original paper. Shown is the central works-packed core, optional tele-scoping observation & EVA tower, antenna, heliostat. Docking tube is at left. In this version, a small crater was chosen to make shielding emplacement easier and to allow the frog access to the middle level. Center left: a crude sketch of how the package arrives deflated in a payload bay, and a view of the donut hostel and docked frog from above.

NOTE: Once the paper was in the mail to make the publication deadline for the conference proceedings, we thought of yet another promising configuration. In the "trilobite", the core works cylinder lays on its side suspended between two larger inflatable cylinders. The area below the core cylinder forms a sheltered bay or ramada for vehicles and routine EVA.

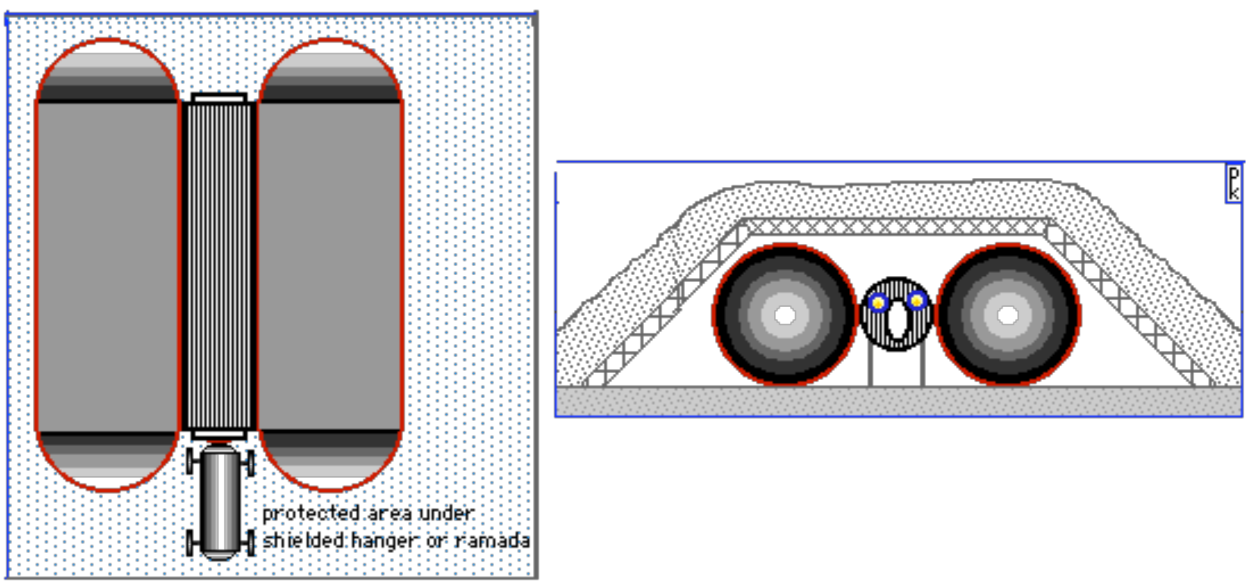


Figure 8: The Trilobite: The works core module could be scaled to a 15' wide shuttle payload bay or to a 27' wide faring atop an External Tank, with inflatable cylinders proportionately sized. Here, the trilobite hostel sits under a shielded hanger, making servicing and expansion much easier.

If hybrids are designed as connectable modules for expansion, the vehicle docking port design chosen for standardization should also serve as a module to module connect. This will offer the greatest versatility. Where rigid ribbing cannot be included (all the above designs except the "slinky") hollow ribbing with post-inflation filling with rigidizing foam could provide structural support if pressurization was lost. However such a foam must be carefully formulated to drastically minimize noxious outgassing as we are dealing with sealed structures that can't be 'aired out'. The hybrid, while still more limited in size than the pure inflatable (though it comes close in the torus format), offers measurably greater usable floor space than a hard-hulled module designed for transport in the same hold, yet can be full of convenient built-in features. The hybrid, in comparison to the retro-furnished simple inflatable, offers comparable savings over rigid shelter in total imported mass. Thus the hybrid inflatable seems to be the best of both worlds. We have only begun to scratch the surface of this promising world of hybrid inflatable design, and present our first fruits for your stimulation and input. ###

MMM #51 - December 1991

Maintaing Fresh Air - Avoiding Use of Combustibles

On the Moon, our habitat and working spaces will be pressurized, sealed off from the external vacuum. Thus it will be a struggle to maintain fresh air, and above all, to avoid any possibility of fire. Our analog environments should be built and furnished accordingly. We may not be able to seal them tightly, but we can try to test methods and materials that will give us success on the Moon.

EVERFRESH

By Peter Kokh

A strange thing happened on the road to energy conservation after the first oil crisis in the late 1970s. Totally insensitive to the micro-sources of air pollution and the need for their co-management along with the thermal control, which had our full attention, people all over the winter-experiencing world began tightening up their houses. A problem, which we never knew we had because it had been effectively neutralized before, suddenly emerged. Both houses themselves and the activities of those within them generate substantial amounts of domestic air pollution. Happily, in our anything-but-tight construction methods of the past, these indoor pollutants along quickly enough dissipated through cracks and openings to the “outside” along with warmth bearing “stale” air to be replaced with cool “fresh” air from the Earth’s generous atmospheric envelope, whose transcendental ambience and carrying capacity we all take for granted.

As we buttoned up our homes and office buildings to conserve heat and reduce the need for heating fuels and/or electricity, we also dammed up a river-flood of indoor air pollutants, a river with many tributaries. Suddenly, for those who had spent good money to make the “improvements”, their indoor air was significantly more polluted than the “outside” air to whose declining quality we had all become sensitized.

Fortunately, there has been an “easy” sweep-it-under-the-rug solution: air exchangers, which trade inside air for ‘fresher’ outside air but make a thermal swap in the process. There has been much less attention, unfortunately, to genuine and radical solutions: getting rid of sources of indoor air pollutants in the first place. It is a story of shortsighted economics and simple convenience.

This experience does not set us up well for future life on the space frontier. Beyond our womb-world, we will not have any all-enveloping placental atmosphere to keep us blissfully cozy. Each settlement will have to contain and conserve its own “atmospherule”. There will be no “outside fresh air.” There will only be “inside air”, and in the cases of megastructures like O’Neill cylinder and Stanford torus space colonies or Bova/Rawlings Moon Plaza and LRS’ Prinzton vault-spanned lunar rille-bottom villages, a very finite amount of “middoors” air that simply cannot be used as a dump sink. A "charter-concern" of off-Earth "xities" will be to maintain air freshness within those limited confines. We can't allow the air to get stale in the first place!

Building materials and furnishing materials that have high outgas flows when new (new car smell, which is nice so long as we can control its intensity by opening the window or vent) will be taboo, to be replaced by those with tolerably low outgas flow rates. Fortunately the offending materials are all organic or synthetic, something that cannot be economically produced on the Moon nor in nearby space settlements dependent early-on largely upon lunar raw materials; and the cost of upporting them out of Earth's gravity well may continue to be a prohibitive economically-suicidal luxury even if transportation rates fall. Equally happily, the building materials that we can produce on site (metal alloys, cast basalt and ceramics, concrete, glass, fiberglass, and glass composites) are all inorganic materials with significantly lower outgasing.

Synthetics cannot be avoided altogether and for pressurization sealants and lubricants, as much attention will have to be paid to the their outgassing contribution as to the percentage of native (lunar-sourced) content (oxygen, and silicon for carbon substitution). To our knowledge, no work is proceeding along these lines, though undoubtedly, by serendipity, research to date must have uncovered promising avenues for further exploration. But enormous mountains of "filed: no economic use" research data must be "mined" to get at these clues. And space supporters who work in the chemical and petrochemical industry are the ones that have to be motivated to do the necessary detective gumshoe work.

Of late, we have all become aware of a new source of indoor pollution - radon, produced in the Earth's crust by radioactive decay and working its way up through microcracks, some of it eventually into our basements. Again, in the era of looser homes, this was a problem below the threshold of concern. The potential for radon problems on the Moon are unknown. But the general rate of radon seepage is one of the things that ought to be weighed in the process of base or settlement site selection. But perhaps we ought not to be overly worried as the both the relative extreme over-pressurization of lunar habitat space (in contrast to lunar vacuum) and the attention to sealants and leak detection that will be in force to maintain and contain pressurization (the expense of replacing leaked atmospheric nitrogen, exotic to the Moon, being the 2x4 poised to strike between our eyes) will work to force crustal radon to find other avenues of escape.

Then there are the pollutants that come from life activities: housekeeping, food storage, cooking, laundry, and personal hygiene. In the lunar or space settlement kitchen, the need to minimize rather than dissipate odors, the need to minimize aerosol oils production (if you've ever lived with anyone whose culinary skills are limited to frying, you know only too well what a problem this can be), and the attendant humidity control problems poised by steam will all force major changes in the way pioneers prepare food. Frying will be a no-no as will, of course, be barbecuing.

Open boiling will also be taboo. Even the oven will be frowned upon. But that does not leave us with a diet of uncooked and/or cold foods, though the proportion of these will probably strike a healthier balance. There remains the friendly food-zapper, provided the concerns of some about microwave emission dangers prove unfounded. But, when taste and flavor are more important than convenience, there is an old standby waiting in the wings, now largely in disuse except by a dying generation of grandmothers: the old-fashioned pressure-cooker, tops for speed, flavor, texture, and odor and steam control.

A word about barbecuing: while domestic BBQs may be taboo (there being no "outside" porch or patio but only tightly controlled and policed "middoor" ones) specially licensed restaurants with their own separate and expensively recycled atmospherules may offer char-broiled steaks, ribs, and chicken - if the meat can be found for an affordable price!. Eating there will be much more expensive than dining in the most expensive five star French restaurants here on Earth.

A companion problem, not to be treated lightly, is storage of food. On Earth, we consider that if someone doesn't mind accumulating preserves of spoiled produce, meat, and leftovers in their pantry, cellar, or refrigerator, or pay attention to the control of in-house food waste composting systems, that is their problem. In the closely shared finite air supplies of off-Earth settlements, it will be everyone's problem. The low priority now given to education on good housekeeping practices will need to be drastically altered. The same goes for accumulations of unwashed soiled clothing.

Bathroom odors are a separate problem, one which we treated in our article "Composting Toilets" ["Compostlets"] in MMM # 40 p5 NOV '90. But for these and cooking odors that can't easily be reduced below a stubborn minimum, a system of stale air 'sewer' and 'drainage' ducts from key localized areas and eventually exhausting into agricultural areas for natural refreshening, will constitute a unique new xity utility service.

The problem of humidity-control we have already mentioned. In the limited shared atmospherule, plant transpiration alone will produce excess humidity, a potentially severe source of mold and mildew. Dehumidifiers will be the logical source of the fresh water supply, organically dirty but chemically clean used water being used for irrigation in a natural cycle. Priority attention will have to be given to dehumidifier housekeeping to avoid such things as potentially community-wide outbreaks of Legionnaire's Disease.

Next in concern are household cleaning and surface maintenance agents. Many of those in common use on Earth are far too aromatic and far too productive of air pollutant aerosols to be approved for space frontier use, domestic or commercial. In some cases, a light adjustment of formulation may remove the offending characteristics. In other cases brand new or discarded old substitutes will need to be found, or rediscovered. Happily, the challenge posed by today's tightened homes will gradually promote the appearance of acceptable alternatives by marketplace economics.

Now we get personal. Even outdoors, we've all on occasion encountered the person who has either chosen to mask the odors of neglected personal hygiene, or compensate for a self-image of sexual inadequacy, by using enough perfume or cologne to make a French harlot seem puritanical, notifying all within fifty feet of his or her approach, even in a a stiff wind. On the space frontier, aromatic intensity of available cosmetic preparations will be tightly controlled, and almost all those currently available on Earth will be contra-band. A stress of personal hygiene and attention to more subtle ways of personal image building will have to substitute.

And smoking? Without a profligately generous atmospheric fresh air sink all about, public smoking will be totally taboo, and private smoking allowed only in spaces, home or private club, expensively provided with quarantined separate air recycling systems.

We've all met people with green thumbs, whose homes or apartments are a delightful jungle of live greenery. While most everyone likes a few house plants about, what would commonly be seen as "overdoing it" will be the standard in lunar and space colony homes, a cultural norm that doubles as a natural psychological defense response to settler awareness ever just below the attention threshold, of the stark barrenness and sterility of the absolute ultimate desert from which they are separated by the settlement's pressurization containment. It will be a norm carefully fostered by deliberate education. House plants aid in keeping the inside air fresh both by recycling exhaled carbon dioxide and by filtering out airborne pollutants, some plants doing a better job of this than others.

The challenge of mini-biosphere maintenance begins at home, inside. For on the frontier, "outside" is only vacuum. It is one thing that will characterize xity life as drastically different from Earth-normal city life with its laissez-faire attitudes and happy-go-lucky lack of concern. ###

FIRE DEPT

By Peter Kokh

Fire and Man go back a long time together. A natural phenomenon frequently caused by lightning striking tinder dry forest, brush, and grassland, our ancestral domestication of fire for cooking, heating, artcraft and manufacturing purposes played a role in the rise of civilization hard to exaggerate.

Yet fire out of hand or out of place has been one of the most devastating and frightening perils to life, limb, and property. Our response to this danger has been one of fire codes attempting to both minimize the chance of accidental fires and control the spread of fires once begun. Most every community is served by a paid or volunteer standby Fire Department. In most cases, unwanted fires are quickly controlled and potential damage limited. Smoke, and other volatile combustion byproducts of fire, are quickly dissipated by flushing to the circulating winds of the vast atmospheric sink surrounding us.

Alas in settlements beyond Earth's atmosphere, the volumes of air available to absorb fire gasses, smoke, and other particulate byproducts will always be most severely limited in comparison to Earthside. Instead of an atmosphere miles deep above our abodes and over vast thinly populated rural areas, we are likely to have only the few cubic meters per person within pressurized habitat, food growing and work areas and other common places. Even in relatively voluminous megastructures like O'Neill colonies or the Prinzton rille- bottom double vault span design, the available "middoors" common volume will still be so minimal by Earth standards that we will have to forgo a strategy of merely controlling fire.

Having nowhere to flush the smoke and fumes, a settlement that has even a small, quickly controlled fire may face at least temporary wholesale abandonment, the incident a catastrophe out of proportion with previous human experience.

Instead, settlers will have no choice but to adopt a zero tolerance for fire. Their first line of defense will not be an automatic fire suppression system, no matter how elaborate. That can only provide a damage control backup and a futile one at that, simply buying time needed for orderly evacuation to standby vehicles or shelters. Rather spacefolk must accept settlement design strictures all but guaranteeing that fires can't start by accident, and that set fires have nowhere to spread.

Because most combustible materials are organics or synthetics rich in carbon and hydrogen, two elements scarce and exotic on the Moon, lunar towns and early space settlements built principally from lunar materials prior to the eventual accessing of cheap volatile sources elsewhere (Phobos and Deimos, asteroids and dead comet hulks] sheer economics will force the choice of largely inorganic and incombustible building materials, furniture, and furnishings. Commonplace wood, paper, organic and synthetic fabrics, and plastics will become exorbitantly expensive choices reserved for the obscene consumption patterns of the ultra-rich. In there place will be various metal alloys, ceramics, concrete, glass, fiberglass, and fiberglass-glass composites (Glax™). Even electrical wire will, for economic reasons, be manufactured on site with inorganic sheathing in place of commonplace plastics. Frontier houses and other structures simply will not burn.

On the Moon, the low gravity ("sixthweight") will greatly reduce the need for cushions, pads, and mattresses that cannot be easily made of these available incombustible inorganic materials. Early Space Colonies will thus have a second incentive to choose lunar standard gravity rather than Earth normal (the first reason being to allow much tighter radiuses, greatly reducing minimum size and structural mass, significantly lowering the threshold for construction).

The two areas of greatest remaining concern will be clothing and drying or composting agricultural biomass. Cotton, since its lunar sourceable oxygen content is much higher than any that of any other fiber choice, renders it easily the least expensive selection. The need to recycle its carbon and hydrogen content upon discard of items made from it, will mandate processing choices for cotton that are organic and thus happily preclude additives with toxic combustion products. The best strategy may be to isolate (even in fabric and clothing shops) concentrations of cotton fabrics and garments from one another in relatively small caches, each guarded by a sprinkler.

Biowaste and biomass management and housekeeping practices, combining strict personnel training with discontinuous storage in small concentrations below critical mass (but again with one-on-one sprinkler vigilance) should all but banish chances of spontaneous combustion and make the spread of set fires impossible. Special attention must be given to grain and powder storage housekeeping and management.

IN SUM: on the early space frontier, fire "control" departments will provide no security. If a fire big enough does break out, the game would be already lost. But what if, despite all precautions, the unthinkable does occur?

Fire shelters connected to the community by air-]tight fire doors and relative over-pressurization could be provided, doubling as shelter in event of pressurization loss. However such shelters must be large enough to accommodate the entire community on a short term basis. It may be prudent to design the community with enough fully "isolatable" storage and warehousing space or agricultural space to serve emergency needs. For the only way to recover from a fire may be to depressurize, then repressurize the affected area. Since a fire may well leave no option but retreat, there should be periodic en masse orderly evacuation drills for the community at large.

As the constraints on building materials ease through cheaper out-sourcing from Deimos and Phobos and/or asteroids and comets, the taboo on using organic and combustible synthetic materials for in-settlement structures, furniture, and furnishings must not be relaxed. In most space locales we will never have the luxury of enough contained ambient atmosphere to allow a return to our current flush it and forget it strategy.

On Mars, in contrast, thanks to the thin carbon dioxide atmosphere and available water and ice reserves, pioneers should be able to produce inexpensive wood and plastics with almost Earth-like ease. Yet here too, until the far off dawning of some new age of "terra-forming" that installs a planet-enveloping commonwealth of breathable air, human settlements on Mars will labor under the same threat of sheer disaster from even the most miner of fires as will lunar and space settlements. If the Mars settlements are to allow wood and synthetics, it will be wise they do so with constraints that work to isolate them in discontinuous small pockets.

Economics on Earth has made the abandonment of combustible materials unthinkable. Instead, fire is tolerated and we have "Fire Departments" for "control" . Beyond Earth, quite different economic realities will combine with a major exacerbation of the threat posed by fire to make fire truly intolerable, and a strategy of control futile. There won't be any Fire Departments in space frontier towns. ###

Postscript about Fire: Neglected Interior Construction Opportunities

While the landscape surrounding the Mars Desert Research Station "screams Mars" in its coloration and landforms, the construction of the Hab interior gets an "F' for not taking the opportunity to simulate interiors that might be possible or plausible on Mars, or on the Moon for that matter.

Walls are of wood 2x4 construction with drywall surfacing, combustible paints, wood doors and more. The path taken was one that was cheapest, and used common skills. After all, the Society was in a hurry to get each station up. Haste makes waste! The Society would be liable for loss of life in any fire inside. Fortunately, such a mishap has not happened.

Steel studs faced with duroc™ cement board, also a familiar technology for some carpenters, along with steel doors, would have been a much wiser choice. Time and money are no excuse. Do it right or don’t do it at all.

MMM #52 - February 1992

The Role of the Campfire

Few things have been so encouraging to the human spirit in unfamiliar places or during inclement weather, as the fireside or hearth. Whether as a spirit-booster against the bitter cold of outdoor Mars, or the even colder lunar nightspan, or just against the unfamiliarity and dangers of new territory, a campfire would be nice. Around the fire stories are told, songs sung, and myths and legends passed on. Many a science fiction yarn has its characters plotting by the warmth of a fire on some star-sunned planet - one with breathable air, of course. But elsewhere in our own Solar System, fire’s mystic magic may be denied us, unless - read on.

Now a fireplace might seem a luxury for an analog research station, but we bet it would be a popular one. And on Moon or Mars, the most essential system is the human one. Maintaining morale cannot be over-valued. Such as setting is an ideal opportunity to evolve hearth systems that might just work on the frontier.

On the Space Frontier, can there be any FIRESIDE around which to gather?

By Peter Kokh

Since time immemorial, ever since the taming of fire, humans have sought warmth, comfort, and company huddled around campfires and hearths. Even today, when a dwindling number of modern homes boast the luxury of a fireplace, nestling around the fire is something we all enjoy - when it is cold or damp, when we’re out camping, on a clambake or a picnic in the park, or just out on the patio or in the back yard for a barbecue or marshmallow roast. And can any of us forget the bonfires after a high school homecoming football games?

While nowadays, such pleasures are scarcely everyday experiences, however infrequently enjoyed, the magic of the fire is so much a universally positive experience that it is still possible to ask: “can it be humanity if there is no campfire?”

In “FIRE DEPT.” [above page 7] , we pointed out the very intolerability of open fire, controlled or not, in the very limited “atmospherules” of mini biospheres. But that is not the last gloomy word, for it only applies to fires in which the combustion products are smoke and toxic gasses.

In MMM # 40 NOV ‘90 “METHANE” we discussed the possibility of controlled burning of compost pile derived methane to produce water vapor along with CO2 for plant nourishment. Such combustion will need to be confined to nitrogen-free chambers so as to avoid unwanted nitrogen oxide byproducts. Could such a methane-oxygen fed flame in a glass-faced chamber serve as a fireplace substitute? Why not?

It should also be possible to devise a tightly confined hearth “substitute” that slowly fed together pure hydrogen and oxygen. If again the burning is confined to a nitrogen-free chamber, the only combustion product would be steam – pure water, which can then be used for drinking or other purposes. In effect, we are talking about a modified fuel cell, in which the 2H2 + O2 = 2H2O reaction is run somewhat faster, not so fast as to be explosive, but fast enough to sustain a flame, perhaps with a harmless enough additive (if one can be found!) to colorize the normally invisible H+O fire.

I'd be surprised if either such device now exists, with little market for them – down here. But out on the frontier, a flame-in-a-jar device might create enough symbolic warmth and cheer to become commonplace in settler homes on the Moon or Mars or elsewhere, in gathering spot lounges, even on long trips aboard spacecraft or surface roving coaches.

Why not tinker up such devices now? The methane version could not be used in draft-tight close quarters but a hydrogen hearth might sell to apartment dwellers, especially singles wanting the latest in trendy mood-setting gizmos. Just knowing that we could take such **"fire chamber"** with us, could make the prospects of life on the space frontier just a little less daunting, just a little more reassuring.

MMM #66 – June 1993

We have to wire (electrify) an analog station, of course. So why not try a system that could work on the Moon? It seems quite possible that a corporation in the business would donate and install such "test systems."

WIRING THE MOON

The order of the day will be to minimize the use of both **copper** wire and **plastic** sheathing

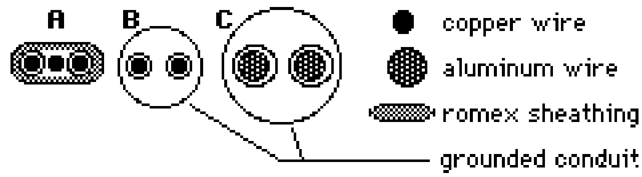
By Peter Kokh

Until 1966, Copper was the exclusive conductor of choice both for long-distance electric power trans-mission and for wiring systems in individual buildings and vehicles. For Copper is both economically producible (since 3000 B.C.!) as well as the best conductor known. In contrast, Aluminum, the second best conductor, was first introduced to the public in this century as a semiprecious metal and did not become truly affordable until mid-century. By the mid-60s, its price had fallen low enough that contractors could save as much as $200 a house by installing wiring systems that used Aluminum.

Aluminum wiring soon earned a very bad name. The problem was that the outlet receptacles used with it had steel terminal screws, an unwise and inappropriate choice that lead to "dangerous overheating causing charring; glowing; equipment malfunction; smoke; melting of wire, wire insulation, and devices; ignition of combustible electrical insulation and surrounding combustible materials; fire and injury and loss of life." So stated the U.S. Consumer Product Safety Commission, plaintiff, in its successful suit against Anaconda and 25 manufacturers and suppliers, in banning "Old Technology" Aluminum Wiring Systems in 1973.

While Aluminum wiring has been little used since, a perfectly safe and CPSC-approved "New Techno-logy" system is available. Very simple: just substitute brass terminal and connection screws. So aluminum wiring systems for the Moon are ready to go. The amount of copper contained in the brass screws is really trivial in comparison to the amount saved by substituting aluminum wire. Until outlet and switch devices can be made substituting lunar glass or porcelain for the plastics now used, such devices – with brass screws – could be simply imported. They do not weigh much and are not bulky.

But that only meets half the challenge. There is the matter of all that carbon and chlorine based plastic sheathing! We could first of all greatly reduce the amount of sheathing needed by giving up modern Romex cable for older technology rigid aluminum conduit (or glax = glass/glass composite) or for the flexible metal conduit (BX) used by an earlier generation of do-it-yourself installers.



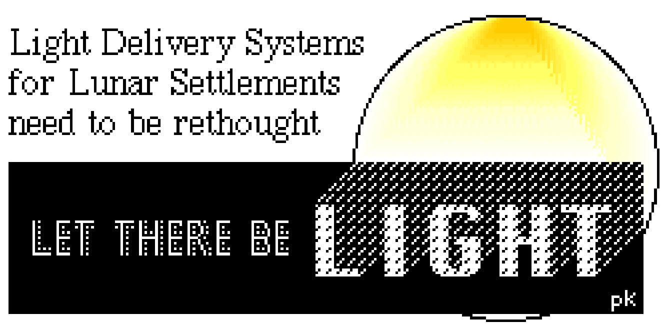
KEY: **A.** Modern flexible plastic sheathed ROMEX cable **B.** Rigid or flexible grounded conduit, copper wire
C. The same with aluminum wire

Either way we save the shared sheath which makes up the romex, and as a bonus (with aluminum conduit) save the grounding (earthing) wire. We'd still need insulating sheathing for the individual hot and neutral wires, and about 67% more of it because of the switch to Aluminum which needs a larger cross-section to carry the same current as Copper.

The next step in designing a lunar-appropriate wiring system is to devise lunar-producible wire sheathing. Fiberglass fabric is one place to start. If you've ever seen a pre-WW II lamp, you may have noticed the frequently frayed cotton fabric-covered lamp cord wire. If some plasticizers are needed to keep the fabric sheathing supple, perhaps some thiosilicone (see MMM # 63 "SILICONE ALCHEMY") could serve.

Other ways to save include lower voltage systems (like the 12 volt systems used in recreational vehicles and remote site cabins) and tighter, more centralized distribution networks. On this, more below.

Finally, a considerable amount of copper is used for the wire bindings of electric motors and generators. It will be desirable to begin producing early on the heavier commonly needed motors and generators on the Moon. Has anyone experimented with aluminum motor bindings and gotten past any initial discouraging results to produce something workable? MMM would like to know. If you know, write.! ###



To minimize the mass fraction of bulb and other light system components that must be imported, careful, even novel choices might be in order.

LIGHT DELIVERY SYSTEMS FOR LUNAR SETTLEMENTS NEED TO BE RETHOUGHT By Peter Kokh

I have never seen a reference that gives any indication that anyone else has ever considered the unwelcome problems posed in the continued importation to a lunar settlement of lightweight but bulky and fragile (therefore over-packaged) light bulbs and tubes. It would seem to me that the lunar manufacture, or at least final assembly, of such devices would be somewhere in the upper third of the list of priorities. The problem is that each of the growing number of diverse lighting bulbs and tubes incorporates some elements not native to the Moon in economically producible abundances.

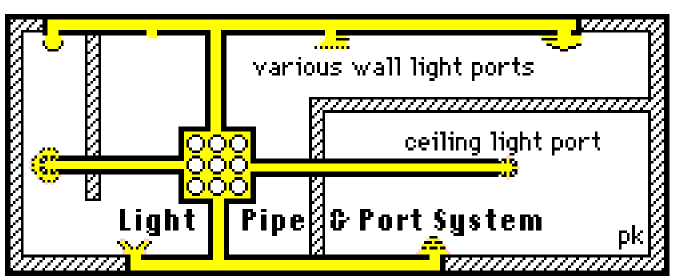
Our familiar everyday **incandescent** light bulb is quite reliant on tungsten wires and filaments for which there is NO practical substitute. The amount of tungsten involved is, however, trivial, and could be affordably imported, preformed and ready to be assembled with Made-on-Luna glass bulbs and mounts. The screw-in or bayonet base can be aluminum with a minimal amount of brass needed for the contact points. The evacuated bulb can be filled with lunar Argon gas. Available coatings include phosphorus produced from known regolith KREEP deposits. Light bulb manufacture is among the most highly automated, with about a dozen people needed to make most of the incandescent bulbs used in the U.S. (per manufacturer). Lunar production would not hog precious person-power.

High intensity halogen lights would necessitate the importing of either bromine, iodine, or fluorine gas along with tungsten filament. To save energy, other light bulb types and fluorescent tubes may be are preferable. But energy savings must be weighed against the gross mass of ingredient materials required that must be imported on an ongoing basis.

Early **fluorescent** tubes were filled with mercury gas and had UV-sensitive phosphorescent coatings of calcium, magnesium, or cadmium tungstate; zinc, calcium, or cadmium silicates; zinc sulfide; borates of zinc or cadmium; cadmium phosphate; finally calcium phosphate. Only the last would be a good choice for lunar manufacture.

In addition to the phosphor used, a relatively small amount of activator to facilitate its excitation is necessary: among these copper, silver, antimony, and bismuth are not lunar-appropriate; thallium may be so someday; and only manganese will be available locally any time soon. However, the small amounts needed should not be a problem to import. Greater challenges are the sophisticated process needed to produce the coating in 2-8" size and the organic binding material needed to coat it on the glass.

The recent development of **Light Pipe** technology suggests an altogether different approach to indoor lighting on the Moon. Instead of a multiplicity of individual lamps and light fixtures, a network of Light Pipes whose rib-faceted inner surfaces channel light without appreciable loss to locations remote to the light source could be built into each building, ending in appropriately spaced and located Light Ports. A central bank of efficient high-pressure lunar-appropriate sodium vapor lights could feed the network during nightspan, sunlight feeding it by dayspan, to form an integrated light delivery system, part of the architect's design chores. Delivery Light Ports could be concealed behind cove moldings to produce ambient ceiling illumination or end in wall ports that could be mechanically variably shuttered or dimmed from full "off" to full "on". If the reverse side of such shutters were mirrored, the 'refused' light would just go elsewhere and not be lost. A low voltage feedback loop could match supply, the number of central bank lamps "on", to the number of Light Ports open.



Wall and Ceiling Light Ports could then be fitted with any of a growing choice of consumer purchased and artist designed decorative plain, etched, or stained glass; or pierced metal diffusers; or fiberglass fabric shades. Such a system might allow the number of types of bulbs that need to be manufactured to be minimized, allow the use of the most efficient bulb types, appreciably reduce the amount of wiring needed, and still allow wide decorator choices. ###

PS. Light pipe systems, fed by sunshine during the day/dayspan, could be fed by high luminosity sulfur lamps by night/nightspan – something else worth demonstrating at an analog location.

PPS. Would some company developing light pipe systems be willing to install a "test system" in a lunar analog station? We think that they might. Many systems that would work on the Moon (or Mars) might have features that would make them marketable on Earth for various applications. This is even more so in the current climate that is favorable for the development of promising "green technologies." We need to identify such systems. This is a way to get part of our construction expenses paid for – as an experimental expense.

MMM #67 – July 1993

"Demo or Die" – Advice with a Warning

In the early days of SSI, Space Studies Institute, technology demonstrations were the order of the day. There is nothing like a convincing demonstration to win over the skeptic. But SSI seemed to drift into paper studies and with that, the magic spell was over.

If we are to have a significant enough effect on the powers that be controlling decision making, including corporations, we need to get back in the business of demonstrating key item by item each engineering and technology piece of the space settlement scenario puzzle. Without demos, the future we paint for the public and our leaders lacks convincing oomph – believability.

Not all the disparate space organizations in this country acting together in some too good to be true coalition can field the whole complex of equipment needed to open the space frontier. That takes megabucks that are beyond our collective powers to raise or spend.

But while we cannot build full-scale operational hardware, in many cases we can build small-scale demo units that convincingly demonstrate critical principles and aspects of technologies that might then catch the attention of corporations and government agencies. The "ground floor" is always the cheapest, and for many of the engineering developments seen as necessary, nothing at all has been done beyond paper studies. We can find our niche here. And if we do not move to occupy that niche, it will stay empty.

Shy of demonstrations, the specter of unknown but possible showstoppers looms to demolish confidence in the future playing into the hands of those with other priorities for political attention and spending. Given today's climate in which the momentum of space development is clearly falling off, we wither work to "demo" or we'll surely see our dreams die. ###

MMM #75 – May 1994

A SUCCESSFUL LUNAR APPROPRIATE MODULAR ARCHITECTURE
Incorporates these Six Elements:

- Smallest number of distinct elements
- Greatest layout design versatility
- Most diverse interior decorating options
- Fabricated with the least labor and equipment
- Assembled with least EVA & equipment
- Pressurizeable after the least total crew hours

By Peter Kokh

Relevant READINGS From Back Issues:

[Republished in MMM Classics #1] MMM # 5 MAY '87 pp. 5-6. "Lunar Architecture"
[Republished in MMM Classics #2] MMM # 20 NOV '88 pp. 5-6. "Ceramic City"
[Republished in MMM Classics #5] MMM # 49 OCT '91 p.3.
"Lowering the Threshold to Lunar Occupancy: HOSTELS, Part II, 2) Room-loving functions"
[Republished in MMM Classics #6] MMM # 53 MAR '92 pp. 5-6. XITY PLANS II. Modular Versatility

Setting the Tone

If we (consortium, settlement authority, government - applies universally) are not to be overwhelmed by the cost overruns that come from "stretch-outs" rooted in financial timidity and shallowness of commitment, the progression from Beachhead to Outpost (demonstrating startup processing and manufacturing technologies) to Settlement must move along swiftly. Once the level of confidence generated by the feasibility demonstrations reaches a critical point, the settlement must be prepared to grow quickly. Economic self-sufficiency only makes sense if it is achieved without delay.

We will need a way to provide roomy, safe and secure pressurized shelter, i.e. lunar housing, on a just-in-time basis as the waves of settlers pour in, ready to crew the industries that will supply income-earning exports to Earth. Residential units must be completed, utilities installed, with a minimum of crew hours. In contrast, interior decoration can be labor-intensive, pursued slowly over the years. But the habitable shell itself has to be erected 1-2-3.

Assembly-line production of a few modular units that lend themselves to diversified floor plans seem to be the answer. The modules must be designed to connect simply and swiftly - yet securely. This is not Earth: the need to pressurize the whole against the external vacuum is a demanding one.

Speed is just one half of the coin. The other side is the need to hold the labor force involved in module production and on site home assembly to the minimum - so as many settlers as possible can work on production for export. Every part of the design of the manufacturing and construction processes involved must have this labor-light goal in mind.

Materials suitable for manufacturing housing modules

Steel and Aluminum or Titanium may come to mind. After all, that is how we build pressure hulls on Earth. But a reality check shows that while iron is abundant, processing out from the lunar regolith soils the various elements that we may want to use to produce iron's alloy, steel, is a bit problematic, especially since no one seems to be doing needed homework on this question. Yet a serviceable lunar steel alloy is much more of a near term prospect than is producing quality alloy aluminum - especially in the context of a small available labor pool, and the need to keep the mass of imported capital equipment to a minimum.

Another theoretical possibility (homework proceeding without due haste) is that of habitat module shells and components made of glass-glass composites or Glax™. Concrete or Lunacrete is a possibility if economically recoverable lunar polar ice deposits are found. Fired ceramic shells and cast basalt shells have both been suggested, but unless reinforced with fiberglass or steel cables, they might not be up to the job of containing pressurized atmosphere. Our own wager, then, is with lunar steel and/or Glax.

The Size of Lunar Homes – the "Great Home" Concept

We must resolutely and brazenly set aside the notion that lunar settlers shall be forever condemned to endure life in cramped quarters. As long as pre-built shelter must be brought in from Earth, weight limits will work to keep pressurized space at a high premium. Bur by the incorporation of inflatable elbowroom in early expansion phases especially for shared communal functions, "cabin fever" can be kept at bay.

But once simply and cheaply and easily manufactured housing modules have been designed that incorporate local lunar materials almost exclusively, valid reasons for pioneers to continue accepting constrictive personal quarters evaporate.

If it can be achieved within the labor and productivity budgets of the settlement, there is no reason why lunar settlers should not request and receive homes that are spacious by American standards. Indeed, there are good reasons to err in the opposite direction.

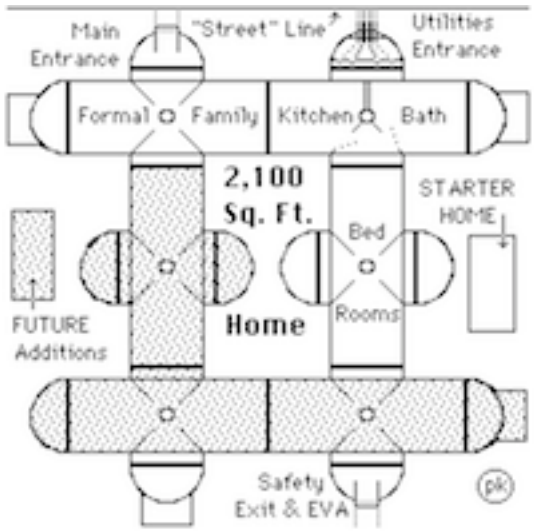
First, considering that lunar shelter must be overburdened with 2-4 meters of radiation-absorbing soil, and that vacuum surrounds the home, expansion at a later date will be considerably more expensive and difficult than routine expansion of terrestrial homes. Better to start with "all the house a family might ever need," and grow into it slowly, than to start with initial needs and then add on repeatedly. Extra rooms can be blocked off so as not to be a dark empty presence. But they can also be rented out to individuals and others not yet ready for their own home, or waiting for one to be built.

Even more sensible is the suggestion that the extra space will come in handy for cottage industry in its early stages, before the new enterprise is established, matured, and doing enough business to be moved into quarters of its own. At the outset, with every available hand employed in export production, the demand for consumer goods, furnishings, occasional wear, arts and crafts, etc. will have to be met in afterhours spare time at-home "cottage industry". The lunar "Great Home" could meet this need elegantly.

"A Minimum # of Modules"

Below are shown 2 basic modules: a 4x12 m (= 13x40 ft) cylinder with open ends and expansion openings to each side. These units can be chain-or-cross-linked, but ultimately, all remaining openings must be closed by an apse or hemispheric cap. Four versions are suggested: simple blind cap; cap with door (to the "street" or to an EVA airlock); cap with periscopic "picture window" unit, and cap with utility service entrances: fresh/drain water, fresh/waste air, electricity, telecommunications, etc.)

Our suggestion is to concentrate water-using functions in a a cross-T module with a side utility entrance cap. Two phases are shown. But we recommend the whole complex be built together.

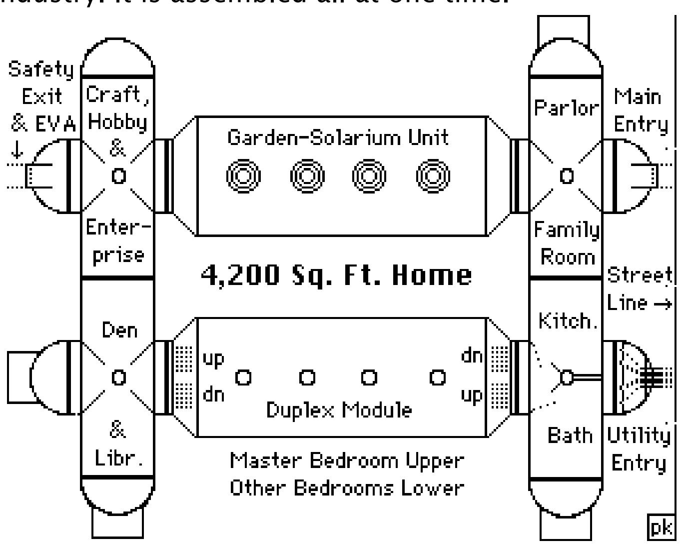


Add a third larger module and presto!

As soon as the settlement module manufacturing facilities are able to produce longer, larger diameter units capable of being configured into two floors, more spacious homes can be built with less modules on less land. At right is a "Great Home" plan that incorporates two of the larger 6x20 m (20x66 ft) modules. One has a master bedroom above and 2 or 3 smaller bedrooms below.

The other has no middle floor but is equipped with larger sun ports and houses a Garden–Solarium that quite literally brings the home to life, producing herbs, spices, and fruit and vegetable specialties for home use and possible sale. The unit includes a patio for nature-revivifying rest and relaxation.

This spacious Great Home or Mare Manor includes ample space to pursue hobbies, even to start up a cottage industry. It is assembled all at one time.

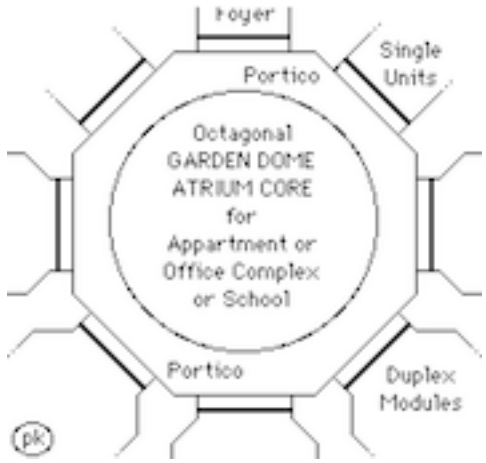


The settlement will need more than homes

As it grows, there will also be a need for larger constructs to serve as apartment blocks, office complexes, schools, clusters of shops, and so on. One way to combine the three modules previously described in larger clusters is to provide a larger polygonal atrium module. We chose a 12 m (40 ft.) diameter octagon for our illustration, simply because our MacPaint drawing program doesn't do hexagonals well. Here we have an atrium floral and foliage garden with a peripheral portico balcony leading to the entrances of other single and double-floored cylindrical modules.

Other specialty connectors could introduce even more diversity in module layout options. Hex nodes, equilateral Y nodes, Y nodes with the fork separated by 90° instead of 120°, longer, and wider cylinders, torus segments etc. The result would be an ever more expressive homegrown architectural "language". Yet the 4 basic modules shown here should be able to put together a respectable town.

Not to be forgotten are the larger diameter cylinders with side ports of which the settlement's residential and business streets are made.



The search for the best modular architectural strategy, one that meets all the challenges listed at the outset of this article, will certainly benefit from being tackled by many minds. The sketches above are suggestions. Perhaps there are far better solutions than those that have occurred to me.

The Apse or End Cap - Challenge or Opportunity

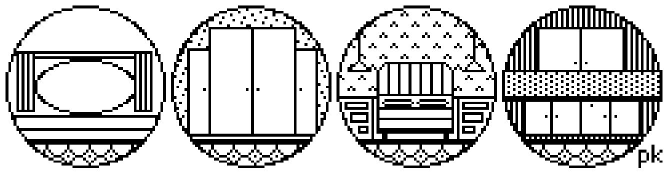
In comparison with terrestrial homes of what-ever style, the distinctive feature of homes on the Moon (or Mars) (that are not within an atmosphere containing megastructure) is their curves. The structural stresses imposed by pressurization and the need to minimize failure constrain basic shell choices to sphere, cylinder, and torus, and combinations of the above. Floors will be flat, of course, as will be added interior walls. But decorating and furnishing outer side walls that are curved will present challenges. The ways these challenges are met will contribute much to the distinctiveness of Lunar (and Martian) Homes. If you look again at the design offerings on the preceding page, you will notice that on average, the cross-T cylinder module, with 4 vectors for expansion, has other cylinders at 2 points, and apse end caps at the other two. These hemispheric alcoves seem to be everywhere.

Will the Lunan homemaker look at these odd-shaped spaces as nuisances, places to stuff odds and ends or stick something distractive? I rather suspect that instead a number of enterprises will arise that find a suite of ways in which to turn this layout liability into a real asset. While these end caps will probably be erected as empty shells - some of them with factory installed entrances or "Z-view" windows, others with factory installed utility service entry connections, others plain and "empty". And as usual, those who come up with ways to productively fill such alcoves will find a ready market for their "product" among those less creative or imaginative. There is a market here, not for factory installed "built-ins", but for post home-raising tailored "snug-ins" with a built-in look. This thoroughly standardized space is the perfect opportunity.

Some obvious solutions are:

√ closets and storage units;
√ a non-hide-away version of the same thing;
√ audiovisual entertainment centers;
√ dinning room buffets;

√ kitchen cabinetry and pantries;
√ library-den shelves and cabinets;
√ bathroom equipment;
√ “Murphy bed” type fold down beds with night stands, lighting, etc. for a supplementary bedroom;
√ breakfast nooks;
√ devotional center or chapel;
√ an exercise center; you get the idea.



We have not yet talked about interior wall decor (next issue) or distinctive lunar-appropriate furniture and furnishings (later issues). But the architectural implications for lunar home interiors are already becoming obvious and interesting. PK

> **Note:** If our analog station is one designed to grow, just as an outpost would on the Moon, then these modular architectural concepts are worth modeling. It is one thing to sketch something out on paper. The process of creating a real model, especially a full-scale one, may reveal problems that need to be addressed, as well as opportunities that we ought to explore.
> **And then there may be potentially profitable applications right here on Earth!**

MMM #76 - June 1994

Manufacturing and Assembly of INTERIOR WALLS

MANUFACTURE AND ASSEMBLY OF INTERIOR WALLS By Peter Kokh

So far, our speculative Lunan Homestead is just a shell, one continuous labyrinthian space. In a pinch, that’ll do. Heck, we can string up a blanket or sheet to provide privacy where needed, but that is certainly no long term answer to the need for structured, subdivided space to house a variety of rather different activities. We will want interior partitions or walls and interior doors and doorways. These can, and will be added afterwards - after construction and pressurization and utility hookup, and after the new occupants take possession. For as we have seen, the need to provide safe basic shelter in as timely a fashion as possible, will be paramount. All other “secondary” shelter needs will have a much lower priority, that is, no real urgency at all.

All the same, how will we provide partitioning? We won’t be able to order a load of 2x4s and dry wall sheets. Even if the settlement farm can produce wood as a byproduct, the young biosphere can ill afford to see its carbon and hydrogen content withdrawn from quick turnaround circulation to be “banked” instead in so comparatively frivolous a pursuit.

If indeed economically recoverable lunar polar water-ice deposits are found, then gypsum, the hydrated calcium sulfate used in dry wall could be produced. To produce dry wall or sheet rock itself, we’d also need a substitute for the paper/cardboard surfaces used to sandwich the gypsum in sheets. Some sort of tight-weave fiberglass might do. This lunar dry wall could then be used with steel 2x4s now widely used in fireproof construction.

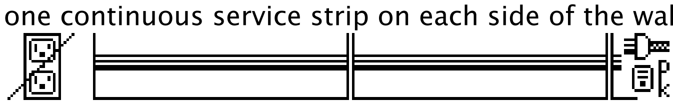
Baring this fortunate orbital prospecting find, and subsequent ground truth confirmation, the more likely building materials for walls are steel and aluminum panels, with steel easier to produce for the early settlement, and glass-glass composite (Glax™) panels, the same likely stuffs used in fabricating the homestead's modular shells themselves, making for consistency in decor treatment . Brick, sinter block, and glass block are likely to have limited application where the permanent decorative look and feel they provide meet the original homesteaders' needs and desires.

Will available building materials be brought into the homestead from the warehouse with fabrication to take place on location with all the attendant dust, debris, and cut off waste? This may be the custom on Earth where the specifications of the particular job vary enormously. But for Lunan homesteads built of lunar-appropriate modular construction elements, the wall-spec variations will form a very limited set. Walls will either fit spherical cross-sections of cylinder modules or center or near-center rectangular sections along the length of the cylinder. In either case, they can be manufactured with in-factory efficiency for onsite snap-fit erection by again designing a very limited number of modular elements.

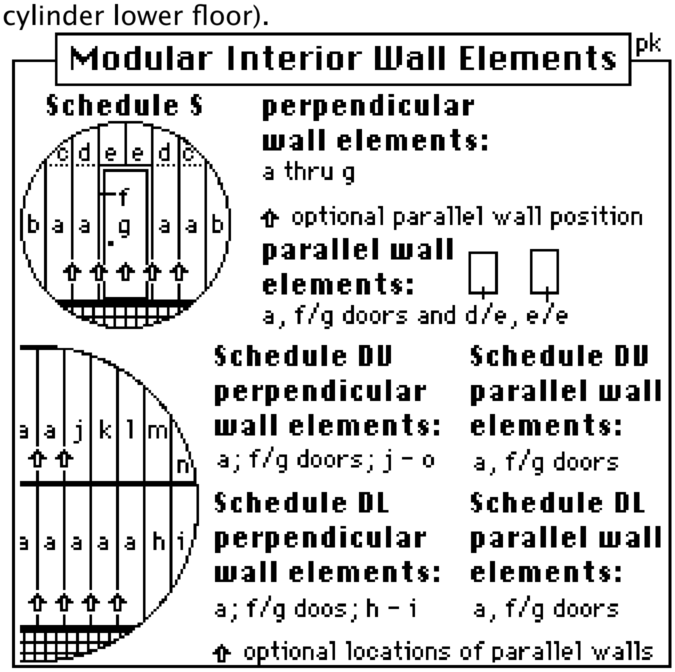
We suggest wall sections of a varying ceiling contour and height but with a standard 50 cm (19.77") width. A double clear space would provide a "rough opening" for a door 1 meter wide (i.e. 30.54", and why not 2 meters i.e. 79.08" high). If each module has a pair of retractable pegs or dowels on both bottom and top to fit matching holes pre-drilled into floor and ceiling on a 50 cm (half meter) grid, the modules could be put together to make a wall easily, and taken apart and reassembled elsewhere when desired.

The modular wall elements could be hollow or honeycombed, with or without inner acoustic insulation. Each of the various elements could be equipped with surface screw actuated KD ["knockdown"] connectors for easy mating. Surface screws would also actuate panel to floor and panel to ceiling pegs or dowels.

The various wall panel elements might also each be fitted with male-female electrical interconnects feeding one continuous service strip on each side of the wall panel.



If our suggestion for modular architecture were to be adopted, 3 principal "schedules" of wall module elements would do the trick: S(single floor module); DU(duplex cylinder upper floor); and DL(duplex cylinder lower floor). ###



on the WALL

Problems & Solutions for Hanging Stuff on the Walls

By Peter Kokh

On Earth, it is no problem to hang something on the wall: pictures and paintings, macramé hangings, copper and wire sculpture, plastic bric-a-brac, mirrors, wall lamps and candle sconces, knickknack shelves, shelving systems, clocks, or whatever else is not too heavy and not too deep as opposed to high or wide. The reason it is not a problem is that the sundry wall stuffs we build with such as plaster, dry wall, and/or wood are all medium density materials. They are soft enough to pierce with a nail or screw, and firm enough to hold such fasteners. Even concrete, brick, and cinder block – all denser and harder – have fastener systems designed for them that are more difficult, but not impossible to use.

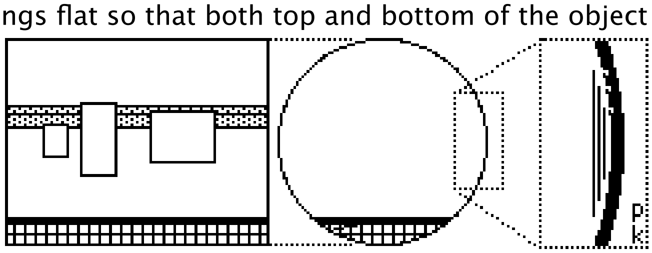
On the Moon, the most probable wall materials are steel, aluminum, and glass-glass composite or Glax™. These are very dense materials, and while it is possible to drill holes into them, “repairing” the “damage” when one wants to redo a room and hang the same or other items elsewhere, exposing old wall-wounds in the process, is something else.

Cable-wrapped fiberglass reinforced lunar concrete is a remote possibility as a hull material. Some sort of cinder block is a conceivable but unlikely material for interior walls. For either of these, however, a water-glass-regolith mortar should be available in a wide range of gray shades. But as these wall materials are the less likely, let’s concentrate on the problems posed by metal and glax.

If repairing “nail holes” is the problem, the simple answer is not to make any in the first place. Yet our Lunan homesteaders will want to personalize their quarters not only by room surface decoration (paint, paper, panel, trim) but by hanging arts & crafts items and other objects “on” the wall. So we are faced with a design problem: how to design walls so that hanging things on them requires no added hardware, no added holes, etc.? We could limit ourselves to steel walls requiring only magnets. But let’s brainstorm a bit more thoroughly.

Our settlers will face two situations: (a) curved outer hull walls (either cylindrical or hemispheric concave surfaces); and (b) flat interior walls. Most likely the kind or at least the size and placement of things we will put on curved surfaces will show more restraint than the total freedom we are accustomed to enjoying with traditional flat walls.

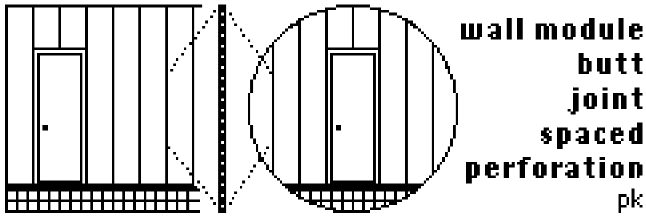
On the horizontally concave outer walls of cylinder modules, only the central portion is suitable for holding things flat so that both top and bottom of the object ‘touch’ the wall.



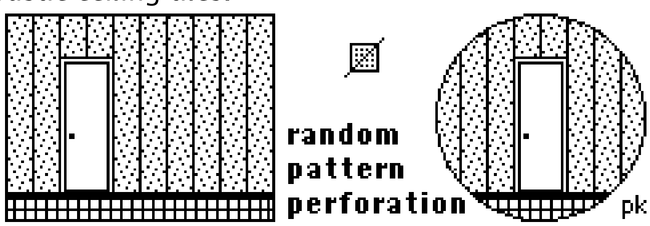
For this purpose, a series of built in hanging strip grooves is a solution that may work, and even presents decorative possibilities, i.e. as a broad horizontal stripe. Objects can be then hung anywhere along the length of the wall, utilizing the hanging groove that best suits their individual height. While the result may be that pictures and other objects are hung slightly below the customary “eye-level”, the hanging grove stripe, perhaps differentiated by texture and/or color from the rest of the wall, will be at the top of this range, serving as a visual corrective of sorts.

This hanging system can be repeated on flat interior walls, especially if one wants to continue the visual effect of the color/texture differentiated hanging stripe. If not, i.e. if one wants more freedom for flat interior walls, then the hanging “stripe” should be visually minimized by not distinguishing the space between the hanging grooves by texture and/or color.

Bearing in mind the suggestion that interior walls be modular, with sections 50 cm or 20" wide, then the butted edges can be "perforated" to allow hanging objects at any height along them.



The constraint of having to space sundry hangings on 20 inch centers may be acceptable to some, not to others. An elegant alternative might be random perforation of the wall panels themselves. The result would not look like "pegboard" for two simple reasons: first, the hole spacing would not be in noticeably vertical and horizontal "rows"; second, the holes would be much smaller, say just large enough to admit a 6d (6 penny) nail, slanted downwards to a depth of say 1 cm or 1/2 inch. The effect, both visually and acoustically would not be unlike that of some acoustic ceiling tiles.



There is, of course, ample precedent for "nail hole control". Many rental and lease agreements stipulate that the tenant or lessee must either repair any holes made, or use adhesive hanging methods – neither a practical option for our settler, given the wall materials likely to be in use. However, much earlier in the present century, it was common to place a "picture hanging molding" just below the ceiling. Anything hung "on" the walls could then be suspended by decorative cords, clips, and tassels from such a molding. That is a look long out of favor and not likely to find fresh converts. But it embodies the philosophy of built in "purchase points" for hanging various items "on" walls that we've tried to borrow.

Again, what we have tried to do is to illustrate the distinctive look of Lunan homesteads that is likely to flow from the constraints inherent in the building materials settlers are likely to have as options. With resourcefulness, such restrictions will trickle through to homes no less custom personalized, nor less beautiful than those left behind on Earth. While options will be less, the possibilities are varied enough that no one will be able to say, "when you've seen one Lunan homestead, you will have seen them all." And in a world many magnitudes of order "smaller" in population, the pursuit of distinctive variety for its own sake will be intensely pursued.

A large part of our sense of world, is not just size, but wealth of diversity and variety – in scenery and terrain, in . plant and animal life, in climate, and in architectural and interior decoration styles. With first just one, then a few more settlements and outposts on the Moon, the settlers will turn to variety in home decoration, not only as the spice of life, but as the principal way of validating their new adoptive satellite as a human world – one with depth. ###

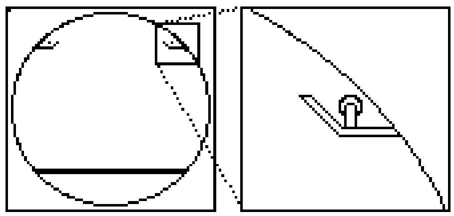
Note: If we build a modular analog research facility and/or visitors' center, we will have the opportunity to experiment with such systems, then market them!

ceilings

pk

CEILINGS By Peter Kokh

How do you define “ceiling” in a habitat space in which the walls curve up overhead and over into one another without any break in the flow? If there is a cove well above eye-level to support ambient cove lighting, the area between the coves might be pragmatically defined as ceiling.



Continuous Cove Light Strip with Reflective Lumination off Ceiling

In some decorating schemes, dark ceilings have been used especially to visually “lower” them when the actual height is too high for one’s taste. Ceilings have also borne lavish decoration. The Sistine Chapel in the Vatican is the most famous example (the one in the Governor’s Conference Room in the State Capitol in Madison comes close enough). But recall also the molded tinplate panels that were commonplace in commercial halls at the turn of the Century (19th to 20th).

But overwhelmingly, ceilings have served as indoor surrogates for the sky, surfaces meant to reflect ambient light brightly. Accordingly they are traditionally painted in flat or other soft white are light pastel shades. On the Moon, we’ll probably see examples of both. The ornate design showpiece may be a high end budget choice as a focus of attention for meeting places, banquet halls, and just plain dining rooms.

But overwhelmingly here on the Moon where the outvac sky is black, the Earth-reminiscent overhead brightness of the sky will be repeated in homestead ceilings as repositories of soft rich unfocused reflected light. For this purpose a waterglass Ti2O (titania) and/or CaO (lime) whitewash should work. If a blue oxide pigment can be produce, we predict sky blue will quickly replace white as hue of choice. ###

flooring

pk

FLOORING By Peter Kokh

In the context of the modular Lunan homestead, three subtopics of interest suggest themselves when it comes to floors and flooring. These are structure – how they are built and installed, function – what purpose these structures might serve besides providing surfaces to walk on and set furniture upon, and finish – what they might look like and feel like underfoot.

Structure: In sixthweight ($1/6^{th}$ G) truss members can be much less massive. We are talking about short 10-20 ft. (3-6 m) spans. Floors and truss/joists can be integral panelized elements, and in the case of two-story applications, incorporate ceiling surfaces as well. Since customer customizing does not seem to be in question, they might best be designed for more efficient factory-installation module by module prior to assembly of the separate homestead modules on site.

Function: if flooring is panelized or modular, ought it be removable? Removable decking could give access to storage space underneath as well as to utility runs (plumbing, ventilation, electrical, communications) connecting the various modules. Yet to the extent trouble free systems are involved, ready access looms as a less important requirement. Nor is subfloor storage especially convenient. More, it might interfere with some finishing options, e.g. installation of ceramic tile.

Fixed flooring could 1) serve most of the utility run needs 2) incorporate a radiant in-floor heating system, the most efficient and comfortable form of heating yet devised, 3) top off a thermal mass reservoir. The latter would be especially attractive if some lunar-sourceable form of eutectic salt can be discovered. [A eutectic salt is one that changes phase from liquid to solid and back at a convenient temperature in the mid ambient range with a relatively large heat input/output i.e. storage/release.] To my knowledge of lunar resources, that is an unlikely prospect, however welcome it would be.

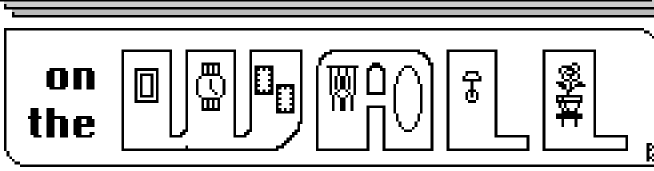
Finish: On Earth, popular flooring choices include carpeting, wood plank or parquet, vinyl tile or sheet (linoleum), slate, and ceramic tile. On the Moon, only the latter is a real possibility, along with steel, glass composite or Glax™, and tiles, bricks, or slabs of cast basalt.

Carpet can be made of natural or synthetic organic fibers. In either case, for lunar application, it would tie up priceless hydrogen, carbon, and possibly nitrogen that is best used to maintain and grow the biosphere. What about carpets made of fiberglass fibers? After all, fiberglass draperies are a common choice. The problem is that for all their strength, glass fibers are brittle and stand up poorly to wear, and other abrasive abuse. For draperies that is not a problem. Underfoot it would never work. However, glass fiber carpets could still be applied to walls, out of harms way, there to contribute to acoustic control and visual softening.

Cast basalt pavers are the one possibility mentioned that deserves the most homework. Baring that, ceramic tile and textured steel, pyrited for color, will be the workhorses. ###

Note; In addition to the opportunities to develop and test and improve such technologies in a Lunar Analog Research Station, doing so in a public Visitors Center will be a valuable investment, bringing across the differences in lifestyles and culture of future pioneers from what we ourselves may be accustomed to.

MMM #77 - July 1994



Part II: What to hang? By Peter Kokh

"Paintings"

As mentioned last month, LRS is sponsoring an effort to pre-develop a line of lunar-producible sealants, paints, and stains all based on Waterglass, sodium silicate hydrate, a liquid and the only known inorganic adhesive. We cannot predict results of our experiments and perhaps we will quickly reach some showstopper. But we have identified a local source of waterglass at only $10/gallon, and we do not anticipate much difficulty in finding local sources of lunar-producible metal oxide powders to use as tints and pigments. A tentative agenda of experimentation has been worked out but this will change, perhaps drastically, as we see how our concoctions behave. Meanwhile, let's assume sufficiently favorable results to support fully lunar-appropriate painting art and craft.

The first thing a painter needs after paints of course, is something to paint on. For wall-hung art, that means a **canvas** of sorts. Among the lunar-producible, inorganic substitutes for common canvas that come to mind are:

- ◇ opaque glass (front-painted)
- ◇ ceramic tablet or tile
- ◇ metal sheet
- ◇ stretched, waterglass sealed fiberglass fabric

Nb. if this application is brittle, then the fabric may need to be stretched over glass or metal support sheet, not just stretched over a hollow frame.

- ◇ back-painted clear glass
- ◇ back-painted unbreakable glax (glass glass composite)
- ◇ vitreous glazes on a ceramic tablet, or tile mosaic

For mass production, once a master has been made or designed (on a computer), computer run machine produced art is a possibility. But given the small market and the need to have something different from the Joneses, the market share for items like this seems small except for cliché paintings of the Earth, settlement site panoramas, and a few other subjects.

Next the painter (or the gallery) will want a **frame**, and possibly **matting**. Glass, Glax, ceramic, and metal frames are possible and may well be mass-produced in stock sizes with pre-drilled top-center hanger holes. Besides the common flat frames, there could conceivably be exterior hull wall contour-following cylindrically or spherically convex frames and canvas substitute painting boards, as a specialty item. Fiberglass fabric covered metal strips in stock sizes may do for matting.

Pictures and Portraits

Portraits may be "painted" using the methods and materials suggested above. They can also be etched on glass or metal, or beaten, bas relief style, in a malleable metal sheet. **Photographs**, however, are a more problematic subject. Cameras will likely be expensive "upports" from Earth for a long, long time. Ditto with film. You can choose to think the settlers will be affluent enough to make Earth-style photo-graphy as common a hobby on the Moon as it is here. I think not. Perhaps a few who do weddings and other special occasion work could make a go of it, but their fees and prices will have to be quite steep. What about a lunar solution? Film substrate is one problem, photosensitive coatings are another (you can forget about silver). If inventors and entrepreneurs could come up with some ingenious lunar substitutes or hybrid lunar-terrestrial solutions intermediate in price, then "standard" camera cases could be locally produced of metal or Glax, to be fitted with optics assemblies upported from Earth, a so-called "MUS/cle" solution. This is really the topic of another article, and yes, MMM is looking for a volunteer to do the research, or assist in doing it. Anyone?

Other wall hung items:

Ceramic and **cast basalt** bric-a-brac items should be fairly inexpensive, depending upon the glazes and special art finishing used. Glass and/or ceramic **Beadwork**, American Indian style or other, using woven fiberglass threads or thin wire, should reach a new popularity. **Macramé** using similar materials with fiberglass cords, or conceivably rescued twine used in packaging sundry items shipped to the Moon, could be another standby.

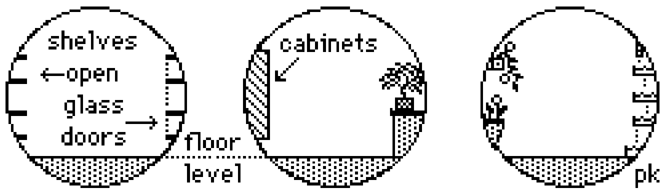
An **aluminum** alloy can replace copper as a medium of wall hung **metal sculpture** and bas relief work. **Wire Art** creations are another easy medium.

Fiberglass tapestries, with embroidered panels perhaps, using fiberglass threads of various color stains may be possible. However, fiberglass threads are rather brittle compared to cotton and nylon, as well as poten-tially irritable to the hands of the artist. Experimentation to devise workable methods for such a craft will be needed.

Stained glass art panels suggest themselves, but do take note of one problem. The caning in universal use to create the cartoon lines of common stained glass mosaics is made of lead, which is most unlikely to be available except at a very dear price. Are their other lunar-producible sufficiently malleable alloys which can be used? Or might the artist bond the individual pieces to a piece of clear substrate glass, perhaps using sodium silicate as an adhesive?

Wall lamps, sconces and wall washers with glass or metal light diffusers or shades should be common enough.

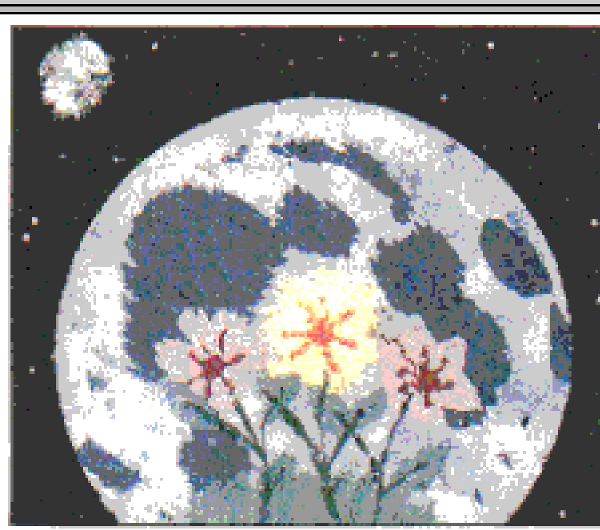
Knickknacks, **shelves** and shelving could be made of metal or Glax (glass glass composite). Some wall-hung curio, display, and other type cabinetry and shelving systems may be custom designed to fit the middle height range of the convex hull shells of the various habitat modules.



Wall hung **planters** of metal, ceramic, or Glax, even **fountains** and water cascades may adorn convex or flat walls. In short, Lunan Homesteads may be as rich in wall-hung items, both functional and beautiful, as homes Earthside. The choices will be meager at the start, of course, but quickly expand as entrepreneurial art and craft cottage industries spring up, their creations sold in weekend streetside bazaars. ###

Note: In a later article, written during our Moon Society moonbase exercise at the Mars Desert Research Station more than ten years later, we suggested art created from scraps and trash. Yes, there will be scraps and trash on the Moon. That which is not biodegradable, or easily recydled, could be put to good use by reworking it into objects of interest and beauty with which to adorn the analog station, thereby creating an example for those who will someday follow.

MMM #80 - November 1994



Lunar settlers will be able to "paint" using only materials derived from the regolith soil around them!

Above is "Moon Garden #1", reverse painted on an 8"x10" piece of glass, by MMM Editor Peter Kokh. The "paints" are not solvent based and incorporate no organic substances even as additives. Instead an inorganic adhesive (the only one known), sodium silicate is used to suspend either raw regolith powder or colored metal oxide powders. The palette is still limited and the art form undeveloped. More candidate lunar-sourceable colored powders are sought, as well as other artists, with more real talent to push the new medium to the fullest.

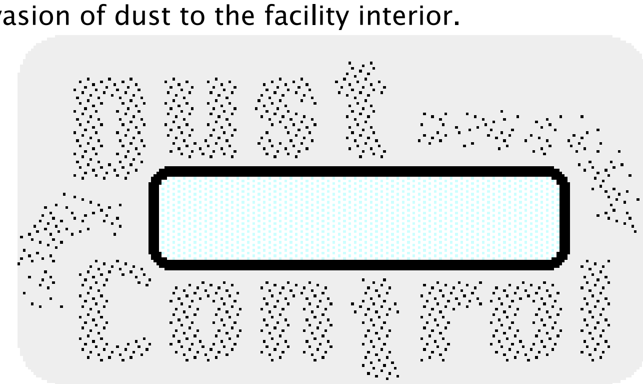
NOTE: Within a year, the paints began to delaminate from the glass pane. The artist tried many things to correct this problem, including wash and rinse and dry routines and sanding the glass with a fine-grit oxide paper, all to no avail. Some 15 and a half years later, he tried again, on a pane of sandblasted glass. At this printing we are waiting to see the long term results.

Another recommended fix is to use potassium silicate instead of sodium silicate. But only proprietary mixtures are available, so that, not knowing for sure what is all in the mixture chemically, the value of any experimentation would be nill. Yet, any and all such experimental art with simulated lunar materials would be great for a lunar analog station environment. ####

MMM #89 - October 1995

The Mars Desert Research Station was a dusty place: poor construction, poor design, sloppy maintenance: in short no good excuse. http://desert.marssociety.org/MDRS/fs05/0310/dcs.asp

The Moon and Mars will be even dustier than the Utah desert. If we are going to create a Lunar Analog Research Station, it behooves us to create a design, and to develop procedures that will inhibit the invasion of dust to the facility interior.



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 structures 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 space-suit 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 settle-ment, if, as seems likely, it would have to be installed in each and every airlock!

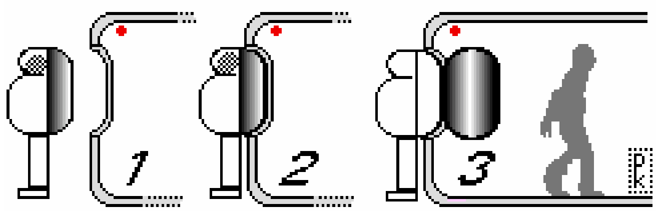
Ballantine Books, New York, ISBN 0-345-32859-0, $9.95

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. **PK**

The "Turtleback" space suit with the "minimal" airlock



Our original inspiration for this idea came from a sketch done by Pat Rawlings for sets to be built for the ABC Movie "Plymouth" shown May 25. 1991.

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, hope-fully 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 code-signed - far from the present case!

The "Dock-Lock"

In addition, we need to equip everything, vehicles and habitats alike, with unisex "dock-locks" for "shirt-sleeve" 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 interconnect-ability, every vehicle and every structure on the Moon will be **interchangeably contiguous**. ###

Note: Both of these design challenges may be quite difficult to meet. But whatever partial solutions to these complex systems we can make will be helpful to those who follow us. It is quite likely that we would have major corporate sponsors for such system developments.

EXPANDING the OUTPOST

EXPANDING THE OUTPOST By Peter Kokh

The provident architect, in designing a building - be it a residence, a factory, a school, an office, or a corporate headquarters - will take into consideration the possible downrange need to expand. For if the tenant of the premises prospers, the structured interior space of the original construction may soon be outgrown. If no provision has been made for easy and orderly expansion, the original site may have to be abandoned, and a new facility built on adjoining or distant property.

Much like the would-be architect using Lincoln Logs or Lego blocks, and even more like the think-ahead Scrabble player, the architect of the original lunar outpost will want to leave a number of opportunities for expansion. His grounded options must provide for changing needs in a flexible way. “Expand EZ” features will mean minimum disruption and disturbance of, and other inconvenience to, ongoing operations

This is the philosophy behind using multi-port nodes as airlock modules, for example. We don’t have to give up a point of access to expand. Spacing of such expansion/access nodes must also be considered. The module or other pressurized space to be added may or may not be of comparable size to the starter module or modules. If connecting ports are arranged at angles to one another, as for example in a cross-T, hex, octagonal or other radial pattern, this provides more sizing flexibility than does an initial configuration with expansion ports arrayed side by side.

Expansion ports should be indifferent to the nature of the added space: hard-hulled payload bay sized modules brought up from Earth; “telescoping” or other-wise unfolding hard-hull modules which allow more usable volume; or inflatable structures. Of these, the cylinder can offer the same or greater volume than the sphere for the same or lower height. And the torus offers a more stable footprint as well as room for built-in features in its “donut-hole” [cf. MMM # 50, NOV ‘91, pp. 6-8 “Hostels: Lowering the Threshold to Lunar Occupancy: Part IV, Hostel-Appropriate Architectures” - MMM C #5]

We have recently touched on another topic which will greatly affect the ease or difficulty of outpost expansion: the manner in which we apply shielding mass made of regolith. If we apply it directly, a certain amount of tedious, gingerly delicate, and messy excavation may be necessary to expose the expansion point decided upon. If we apply our shielding indirectly, as in a hangar shed arch roof over the outpost site, then this shielding will not be in our way when we need to expand, and, as a bonus, the workers affecting the expansion can work in a safer, radiation and micrometeorite free “lee” vacuum under the hangar shed.

The layout of the site must also be considered, and we won’t want to pick a site that unduly constricts opportunities for expansion with too close scenic but in-the-way features like crater walls, rille shoulders, scarps, etc.

Expansion for what?

We will want to expand our outpost in a timely fashion to provide together both more living space and more operations space. In expanded living space will be additional private quarters for more crew, more and better furnished common space, more recreational and leisure space, more space for added life support and food production, even garden space.

Expanded operations will include:

- exploration
- in-the-field prospecting
- mining
- material production
- manufacturing
- product fabrication facilities
- expanded sample and product testing laboratory
- inside storage, etc.

Obviously, reason exists for considerable expansion, stage by stage.

Planning for expansion must be flexible. Some of the things we think we can do and do well enough on the Moon may not work out or present engineering and prerequisite difficulties that mandate putting them off until later. Other unsuspected opportunities for useful and profitable activity that can be supported early on will emerge. The exact sequence of diversification into iron and steel, glass and glass composites, ceramics and cast basalt, and lunar concrete, should be kept provisional and open to unfolding realities of need and ability. Expansion must then be both flexibly preplanned and opportunistic. This is in fact how things unfold on Earth. It will be no different on the Moon.

Addition of “Out-Facilities”

Initially, the outpost will be quite compact and integral with the only peripheral installations being solar arrays and radiators, antennae, tank storage farms, the space pad, power generation and storage etc. But he time will soon come when we will want to move industrial operations that have passed their field trials out of the ‘incubator’ space within the original outpost complex into new, more spacious, and more rationally designed industrial quarters more or less nearby. Such industrial space may be connected to the outpost by a pressurized corridor tube or passageway of some sort, or it may be accessed, also in shirt sleeves, by a docking personnel transport coach. However, if the facility uses a lot of raw materials “mined” at some distance, the whole industrial operation might better be placed at a suitable site handier to the source.

Another unconnected complex likely to arise early on is a “Port Operations” facility at the Moon base space pad site, as the pace of expansion increases and with it the amount and frequency of traffic between base and Earth and/or Earth orbit. Additional “exclaves” may be at an astronomical observatory installation within logistical support range of the outpost, and even a sort of getaway recreational retreat, say on the scenic rim of a large not-to-hard-to-reach crater or rille. ‘Androgynous’ dock-locks will make such actually separate installations functionally contiguous allowing easy, safe, and comfortable passage from one to the other. Keeping pace with all this will be an expanding road network, reworked as need be to handle more frequent and heavier traffic loads.

Room for Visitors

At first, there will be no room or provision for “non-working” visitors. As the outpost expands, spare quarters for guests may be set aside (possibly the original, now outmoded crew quarters). Only as the outpost expands to the point where potential income from visitors outweighs the “bother” that looking out for them will cause, will a real ticket-purchasing visitor influx begin. The outpost will then have a dedicated hotel, a tourist excursion coach, and an itinerary of visitable sites. And outpost population will have grown quite a bit.

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Note: As an analog operation grows, we may want to model some of these expansions and out-facilities,

PERSONNEL

From Scout Crews to Pioneer Settlers

Expanding “tours of duty”, “reenlistment” options, partners & pregnancies, cabin fever prevention, etc.

By Peter Kokh

This article addresses some issues that would not be applicable to an analog operation. However, issues which concern morale, even over short tours of duty, will be essential at an analog operation as well, if tours are longer than the standard MDRS two weeks.

Time off:

Sabbatical week "vacations" would be a very special perk, one that the "reupper" can use to explore in greater depth any hobbies or interests — experimenting with lunar art/craft materials, dance forms that go with the grain of sixthweight, exploring and developing confined space sixth-weight sports ideas; music, poetry, literature, and writing articles for hire reporting on life on the Moon. It is important to realize that all such activity can be indirectly productive for the basehold as a whole if and in so far as it opens up more possibilities for other personnel to enjoy their stays.

Attention to ambiance:

Not all the perks should be reserved for those who agree to duty extensions. By then the psychological damage from unnecessarily spartan conditions may be irreversible. The outpost can be made both ergonomic and functionally pleasant at little or no extra weight penalty or cost simply by thoughtful design. Crew quarters can be individually decorated, and easily redecorable to suit the tastes of new occupants. There should be varied and redoable decor in the common areas. There should be cubbyholes other than one's own cramped berth space in which to retreat. Attention should be paid to acoustics so that one has the choice of background music or silence or his/her own favorite blends.

Rotation of assignments:

No matter what one's specialty, there should be the opportunity for shot-in-the-arm routine-busting assignments. Those regularly in the field can be given inside duty for relief. Vice versa, those stuck in labs workstations can be given periodic field duty.

Leisure time opportunities:

he outpost should have a good audiovisual and literature library, in the lightest weight storage form, of course. There should also be some traditional art and craft media and the opportunity to explore working with on site materials. Requests should be honored when feasible for "time off together" for those wanting to explore dance or sport or other "exercise" options. There should be "real" opportunities as well for continuing self-education, personal or occupational, for credit when desirable.

A bit of Earth:

Relief duty in the outpost farm, even if nothing but a compact hydroponics closet operation, will be welcome to most. In addition, an abundance of well-chosen "house plants" will not only help keep the air "fresh and sweet", but provide a psychological filter against the barren and sterile surroundings outvac - especially if arranged in the foreground of any window or viewing port. Available nooks and crannies can be the opportunity for "pocket parks", even "forests" of bonsai evergreens.

Good Food:

A decade later at MDRS, the Moon Society crew tried a vegetarian meal, enhanced with soy products such as crumbles, and with a feast of talapia for our banquet meal on the eve of our departure. Talapia are a fish that thrives in greenhouse water systems, a no-extra cost option that was quite welcome. Results were mixed. Good at first, then so-so to boring as we ran out of soy crumbles and other items and had to rely too much on beans.

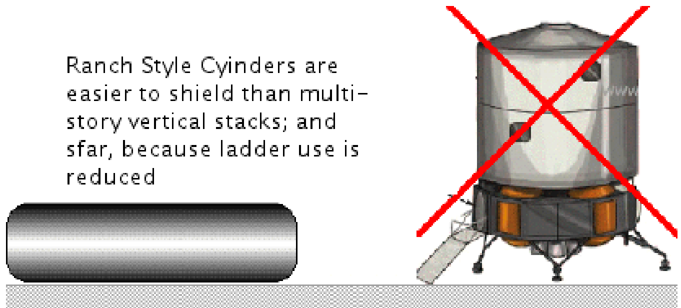
Tasty food and menu variety are essential to morale. It is folly to look for X number of plants that will provide complete nutrition. Nutrition alone will not boost morale. We should concentrate on plants that can be prepared in many ways, as that creates menu variety. One versatile plant is worth a half-dozen that can be fixed in only one way.

A place to get away for a change of scenery and of company

Sometimes, the best cure is a change of scenery. If there is an out-station for whatever reason, a few days on a fresh assignment there can help reduce interpersonal tensions and built-up frustration. Lacking that option, a change in job assignment, even for a short time can help.

There have been countless “Human Factors” studies at MDRS, but two-week tours are too short for many trouble spots to come to the surface. Both crews that I was on (34, 45) had interpersonal problems.

All systems can be go and in 100% working order, but the most critical system of all is the human one, and high morale should get high priority. An analog operation is a good environment in which to test various measures, benefits, perks, and remedies.



MMM #96 - June 1996

Against the Overwhelming Barrenness of the Moonscape

A GREEN SECURITY BLANKET By Peter Kokh

Relevant Readings from Back Issues of MMM
MMM # 8 SEP ‘87, “Parkway”; “Animal Life”
MMM # 50 NOV ‘91, pp 8-9. “Trees”
MMM # 53 MAR ‘92, p 6 “Xititech III. Cellular Rhythm”
MMM # 54 APR ‘92, pp 5-6 “Xitiplans”
MMM # 76 JUN ‘94, p 1 “Windows, a new cliché”

Some of us are house plant nuts, some of us are hobby gardening enthusiasts. But perhaps most of us don’t give vegetation, indoors or out, much thought. We don’t have to. Given the general luxuriant feel of the outdoors, we get enough of a green-fix automatically without having to concern ourselves much about it. And that remains generally true, even in this era in which the health of the host environment is in question, and living nature under siege from selfishness, greed, and simple carelessness.

On the Moon life is not a given. There is none of that comforting green stuff maintaining itself on automatic. The outdoors is lifeless, barren, sterile - relentlessly so - assertively so - threateningly so. Greenery within the protected confines of the mini-biosphere will become a preoccupation of all but the most soulless personalities.

That a healthy abundance of plants contributes significantly and noticeably to air quality and freshness will be a reinforcing motivation. (NASA-funded studies have shown that the right mix of houseplants can be quite effective in reducing household airborne pollutants.) But we suspect that for most Lunans, the real driver will be the need to use plant life as a security blanket, a psychological filter against the out-vac’s life-quenching sterility, much as for smokers, a cigarette makes the world a friendlier place (no, I am not one).

If lunar homes and offices and schools have windows affording moonscape views, inside window box planters of houseplants will take the edge off the life-threat of that magnificent but deadly desolation. But we will find many other nooks and crannies to put plants. Greenery and foliage will become the mainstay of interior decoration. Everything else will play but a supporting role.

A much higher percentage of Lunans are likely to be home gardeners. They will be aggressive in finding opportunities to add plants. Quite possibly a solar-lit atrium space will become the organizing focus of choice in purchaser chosen home plans. Such a space will afford vegetable and herb gardens or a mini-orchard to help with the food budget and menu variety, maybe a tad of entrepreneurial canning. But it could also be devoted to purely decorative plantings of variegated foliage and flowering plants, song birds, humming-birds, and butterflies. Or it could become a more mystical place, a Japanese style sand and stone garden. For despite the general preoccupation with plant life, there will still be a big range of personal sensitivities, and of lifestyle needs.

Architects in general will look for ways to build-in planters and other cubbyholes for plants, providing also for their illumination. Vegetation will be a new design parameter.

Out in the “middoors” too, every opportunity to tuck in vegetation will be aggressively pursued by architects and users. Middoor streets and passageways, inter-sections and squares, are likely to become as verdant as they are busy. This can be the concern of the xity administration, or, more health-fully, of rival neighbor-hood, and street merchant associations, or other stretch-”adopting” clubs.

While green will be the dominant color thus inserted into settlement life (architects and decorators will be motivated to find ways to introduce ambiently lit sky blue ceilings and open space sky blue vaults), settlers may rely on plant life to provide other colors as well. The early lunar art pallet (water-glass-based metal oxide “paints” and ceramics) will be one of generally subdued colors. As helpful as such additions will be, the thirst of the more vivid coloration of flowers (and perhaps birds and butterflies) will be strong.

It is likely that flowering plants will be staggered so that at least something is in bloom every sunth (the lunar dayspan / nightspan cycle). Will flowering plants grow taller on their own in sixthweight? Or can they be coaxed to grow taller? If so, Lunans may be able to savor the delight of floral “forests”. These would provide a must-see tourist draw.

Trees are likely to be of the dwarf variety (many fruit-bearing dwarf hybrids are already marketed), more bush-like in size, at least until the cost of imported nitrogen makes economically feasible the construction of higher-vaulted middoor spaces. In the meantime, to fill the void, individuals and clubs may take strongly to the cultivation of bonsai trees, even to the point of growing bonsai forests, again a tourist must see.

The first parks may be interim floral and grassy meadow refuges within agricultural areas. Even if the farm units are highly mechanized assemblages of trays and racks and LED lighting arrays, the sight of so much greenery (and the freshness of the air) will make any kind of food-producing area a mecca for those living or working nearby.

In the previous article, we mentioned that mini-biospheres will guarantee the reintegration of city and farm, the overdue return to farm village roots and a more nature-harmonious lifestyle-paradigm. Already in this century here on Earth, most developed cities have thinned out greatly in density, giving much more space to greenery (even if still more to pavement, in homage to the great god Auto).

Also on Earth, we have seen a general increase in urban and especially suburban wildlife, a welcome turnaround, led by post-human species, species that have learned to thrive in human-dominated environments. We can hope that Lunans will indulge in the luxury (to bean counter eyes) of urban wildlife. We’ve mentioned birds and butterflies. Surely bees, ducks, swans, flamingos, squirrels, even deer, and more.

In our cities, pockets of life are seen as a concession to nature. In the off planet xity, pockets of humanity will be the concession. Vegetation will play the host. The Xity will be an exercise in symbiosis, man and Gaia reunited. ###

NOTE:

We should take care to design our analog facilities accordingly, not as human spaces with token houseplants, but garden spaces with pleasant places for humans.

⇒⇒||THE QUEST FOR||⇐⇐ ELBOW ROOM

THE QUEST FOR ELBOW ROOM By Peter Kokh

Relevant Readings from Back Issues of MMM

#5 MAY '87, "LunARchitecture" [MMMC #1]

#28 SEP '89, p 5, "Sardine Can Fatalism" [MMMC 21]

#48 SEP '91, p 4 "Hostels: Foreword" [MMMC #5]

#49 OCT '91, pp. 3-7 "Hostel Share of Workload" [MMMC #5]

#50 NOV '91, pp 6-8 "Hostel Architectures" [MMMC #5]

#75 MAY '94, p 1 "Lebensraum"; pp 4-6 [MMMC #8] "Successful Lunar Appropriate Modular Architecture"

#80 NOV '94, pp. 9-10, "Stretching Out" [MMMC #8]

Note: those sections of this article that are not relevant to lunar analog applications are omitted.

"Canned" habitat space

If spacesuits are restrictive, so will be "canned" Made on Earth habitat modules. In the beginning, there will be no easy alternative. On the Moon, local building materials and the factories to produce them and use them to manufacture shelter components will be an early "priority", read "not-immediately-realizable". Competing designs for habitat modules to be built on Earth and shipped to the Moon will be judged both on how compact they are and on how light they are. These are unavoidable shipping concerns with all foreseeable transport options.

There is a long tradition behind sardine can space, much of it in pre-nuclear era submarines. That people on short tours of duty a few months long at best can adapt to such cramped hot-racking conditions with minimal privacy or other personal amenities is well established. Anything is bearable if there is light at the end of the tunnel.

Relief by good human factors design

But a lunar Outpost Interface is not meant to be a military operation. It is a facility that cannot fulfill its mission if it does not foster experimental and even artistic creativity in learning to adapt to an utterly unfamiliar environment with no experience-recognizable assets. The base will have to be much better designed than a W.W.II era sub to foster the high morale needed for success under the challenging circumstances. Pairs of berths used in shift sequence can trade off shared elbow room personal space, via a movable partition. Common areas can be cheerfully decorated and partitioned to create the illusion of more complex, therefore psychologically more generous space. There should be getaway retreats one can sign up to use, and quiet spaces, and noisy gregarious spaces. And there should be rotation of duties, qualifications allowing.

Hybrid rigid inflatables

Well before "in situ architecture" using locally produced building materials begins to supply substantially more spacious quarters for personnel, activities, and operations, hybrid "rigid-inflatable" modules that compact for shipment, and expand upon deployment, all the works and systems in a rigid attached component (end cap, floor, ceiling, or central core). Such hybrids with their fold down, pop out, snap up furnishings opening into the inflatable space out of the attached rigid works section, will solve the frequent objection to inflatables based on the need to spend much time outfitting them after deployment. [see the MMM # 50 reference above.]

These hybrids will allow more generous, if still tight, personal quarters, and common space for recreational activities that could not previously be supported. more importantly they will offer space for more storage of equipment, samples, and experiments — all prerequisites to advance to more demanding mission tasks in the overall framework of learning how to live and work productively on the Moon.

Time sharing and other tricks

Time-sharing of all common facilities by a full three shifts will always be essential to getting the most product out of every facility and piece of equipment per dollar spent and time elapsed. On Earth, the part time use of facilities in line with day shift chauvinism is the single most wasteful aspect of all terrestrial economies. Fortunately, on the Moon artificial lighting sequences allows us to engineer out of existence any advantage of one shift over the other, removing all chauvinism and preferential treatment.

Providing the option of duty reassignment and or the chance to be reassigned to other sites, or at least to visit them, will greatly relieve the symptom of feeling trapped and caged. The flip side is that this need will motivate parties involved to open up ancillary sites, making a humble down payment on an interdependent multisite domestic lunar global economy.

Made on Luna shelter – section omitted **Lavatubes** – section omitted

Altered expectations

The American expectation of some 750 square feet of housing per person, will not translate well to the Moon, nor should it. In the typical room, many spaces are minimally used. Dining rooms for example. Even bedrooms. The Lunan home architect / planner will need to develop multi-use spaces, with fewer rooms that are in fuller use.

Bedrooms can double as office, sewing room, den, or whatever. How? Back to the Murphy bed and the efficiency apartment idea. A bed that is unoccupied and neatly dressed may look nice, but two thirds of the day is just wasting dearly bought space. Dining will be another function that time-shares space with other activities. And so on. Native-born Lunans who've known no other way to live, will look on our homes as expressions of an obscene waste of space.

The Great Home concept – section omitted **The Street** – section omitted

Commercial and industrial space – section omitted **Tricks again** – section abbreviated

Good human factors design can make small spaces seem larger. Important in public spaces will be variety and change of ambiance from place to place. Much as in the Moscow Metro (subway) each station is a totally different work of art remarkable unto itself. Surface finishes can differ. The planting mix can vary.

Mini-biospheres need elbow room too!

It is not enough to relieve psychological crowding for the inhabitants. If they are to thrive, it is even more important that the biosphere be ample and grow, not just in pace with the population, but well ahead of it. That is it should be the goal to quadruple the supporting biomass as we double the population, so that the per capita biosphere support increases to a more healthful, more Earthlike ratio. Not only will lunar settlements see the return of the farming village, we will want to add wilds and nature preserves, greatly diversify the flora as well as the food crop mix, and continue to work in ever more wildlife. Long term, it is only such a development that can secure a settlement's future, advancing it toward biospheric self-maintenance. Also long term, it is only the hope and expectation of continued real progress in this direction that will make lunar settlements psychologically healthy places for Lunans to live and work and raise families.

Conclusion — The quest for elbowroom will be a permanent feature of Lunan settlement culture. ###

Note: MDRS has a design optimized for transport, a temporary need, and little at all consideration of the functions shoehorned into it permanently. For MDRS function follows form, the opposite of the way it should be. The answer, of course, is to add additional modules and move some functions into them, as needed. But this "redesign with use" which would be what would happen in a real Mars or Moon base situation, was never pursued or allowed. Thus MDRS serves as a model of a temporary expedition facility, and not of a true Mars base.

This has been a strategic mistake in our opinion, as watching it grow and develop would have held the public's attention and better help the public realize that establishment of a human frontier on Mars is possible. As that is the ultimate goal of the Mars Society, the MDRS operation, while attracting considerable publicity and funding, has crippled the Mars movement in the long run.

MMM #116 - June 1998

Using Space (and Lunar) Facilities "24/7"

Maximum Science Output - Optimum Crew Morale

By Peter Kokh

USING FACILITIES AROUND-THE-CLOCK Orbital and Lunar habitats and laboratories are very expensive to build, launch, outfit, and maintain.

Most of these costs are fixed whether we man them continuously or not.

Further, all this capital equipment has a limited useful lifetime, beyond which replacement makes more sense than repair and refurbishment. It becomes imperative then to get maximum use out of this equipment - around-the-clock use. Remember that in space and on the Moon, there is no 24 hour day/night cycle.

Any equipment, any workstation, even any sleeping space that is not used on a 24 hour basis is essentially a squandered resource.

For those who have put up the money, be it taxpayers or shareholders, this becomes criminal waste. The International Space Station is a case in point - a very expensive capital investment that may go underutilized for one simple reason. It may not be manned, post for post, on a 3 shift basis. Commercial installations cannot afford to follow suite. Commercial operators do not have bottomless pockets, assured funding regardless of profit and loss. This advice is for them.

Two things emerge:

- We must have a big enough crew to continuously man all posts on at least a 2 shift basis.
- We must have adequate sleeping, recreational, and other needed facilities for a crew large enough to keep all the equipment busy full time. If we do not, our overall plan becomes an absurdity.

'Hab space' must be in proportion to "lab space". While such facilities are themselves expensive, the cost of providing hab space and crew is less than that of letting capital equipment go idle.

VIRTUAL ELBOW ROOM

We can architecturally finesse human space so that:

- Each space lends itself to alternating shift use
- Each space seems more spacious than it really is

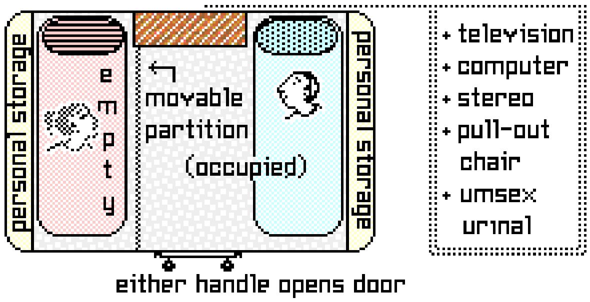
MMM back readings on this topic

MMM # 28 SEP ‘89, p. 5, “**Sardine Can Fatalism**”
[republished in MMMC #3]

MMM # 51 DEC ‘91, p. 2, **Hybrid Rigid-Inflatable Structures in Space** [republished in MMMC #6]

MMM # 80 NOV ‘94, pp. 9-10, **Avoiding Sardine Can Syndrome:** “Stretching Out”: Usage, Layout & Decorating tricks to create Psychological Elbow Room in Limited Habitat Volumes [republished in MMMC #10]

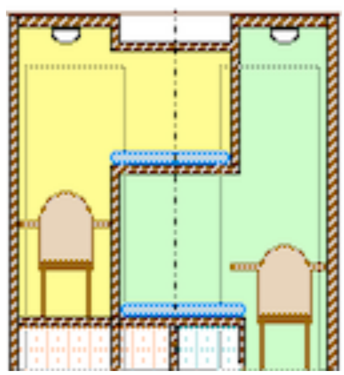
If we can get beyond hot-racking in sleeping quarters to provide individual berths, we can still time-share dead space elbow room between adjoining compartments in alternate use - with movable partitions or with separate doors to shared space



Crew members must have amble space for off-duty activities, not only in common spaces like ward rooms but in their own quarters. This is one suggestion.

ABOVE: Time-share dual compartment. The door has dual knobs and hinges. As occupying person leaves at end of 12 hr. sleep-relax shift, movable partition automatically shifts over and opposite door handle is enabled. Partition can be decorated to individual taste on both sides (colors, photos, paintings, etc.). Only the carpet color and works console is shared. Each person calls up his/her own monitor screen design and his/her own hard disk. Here, each person’s quarters are more than doubled in free volume, while the space of the compartment pair is increased by only half. The partition could be folded back by mutual agreement.

- **Compare** to the interwoven “staterooms” in FMARS & MDRS which are used just 8 hrs a day.



MDRS Stateroom Pair: By borrowing sleeping room space from one another, two units are carved from less space. This is an understandable arrangement fro analog Mars where the day night cycle is just 40 minutes longer than our 24 hour day. But on analog Luna, where the dayspan/nightspan cycle is 29.53 Earth days long, crew could sleep in shifts (at least two) shifting dead space rather than splitting it.

These principles could be realized in alternative designs and with less generous or more ample shared space. For a small investment in volume, each person’s personal elbow-room is increased greatly.

One way to increase “spaciousness” is to cut in half, even to a third, the number of people in any area at any time. We can time share not only work stations but common spaces like wardrooms, exercise areas, hobby areas, etc. Industries know the trick well, some even cycling work week/weekend times.

Other tricks suggested are the structuring of common spaces to support various activities, using dividers to break up total empty space into special activity areas to make the same volume seem larger. Breaking up sight lines is important. A volume that can be seen at a glance is psychologically smaller than an equal volume that needs to be "explored" – i.e. "maze is good". So is unpredictability, varied layouts of duplicated components. If there is more than one hab module, each can have its own layout, decor, and personality. Ditto with workspaces.

Side-by-side work-stations can be baffled, offset, arranged at angles, etc. to personalize the individual work spaces. Clustering workspaces and separating with volumes for other use can also help.

Color is a great divider. Chosen to compliment one another, various hues can make a place so much more livable. Colors can also be changed from time to time. Electrosensitive colors can be changed on demand by the twist of a dial. Photo murals, front-lit or backlit, relax the eye as well as the spirit. They too can be changed to suit occasion, mood, or season.

The design goal is to provide full manning at less expense. Around-the-clock manning means, in turn, plenary return on science equipment investment. So catering to human factors is NOT a luxury. Not to do so, to the contrary, is just plain stupid. Bureaucrats can afford to be stupid, there is no price for them to pay. Commercial operators must fight wisely for every penny of profit, and cheating by cutting corners inevitably costs more in the end.

[Snip part of article applying to in-space situations only.]

IF it is worthwhile to do science and research in space and on the Moon, then it is worthwhile to provide a large enough crew for around-the-clock manning of all posts. It becomes vital not to skimp on crew accommodations and amenities. An unhappy or demoralized or stressed crew will not produce the best results, and that becomes much more expensive than the extra facilities. Max Science needs Max Hab space. Have NASA and others gotten that message? **<MMM>**

PS: How practical are these ideas for analog sites?

- For those analog research centers where there is a strong focus on outdoor activity (simulations of exploration, prospecting, construction, soil moving, etc., a one or two-shift operation will work best.
- But for analog research centers where the month-long lunar dayspan/nightspan cycle is simulated (lunar agriculture, other indoor activities) a rotating 3-shift system would make the most efficient and less expensive use of the required equipment and function space.

MODULAR

A Modular Approach to Biospherics

Designing every Occupation Unit as an EcoCell

By Peter Kokh

Moving off planet (Earth) is much more than a matter of engineering cheap transportation to space. It means moving out of the Biosphere that envelopes and involves Earth's global surface layers (air, the land, soil, water) and everything in them. It means moving to an area, whether in free space or on the surface of other bodies in the solar system, where we must create biospheres from scratch to live within.

Even the problem of "designing" "stable" mini-biospheres seems quite daunting, discouragingly replete with too many parameters to be taken into consideration. The globally followed Biosphere II experiments in Oracle, Arizona were widely reported and still believed to be a failure. Such an attitude angers us and fills us with contempt at those who report or parrot such conclusions. First, nothing is a failure from which lessons are learned. Second, there is no other path to success than a pyramid of so-called "failures".

But what we did learn from Biosphere II is that finding a successful "equation" is much more challenging a problem than we had hoped it would be. We suggest that that is because we are going at the problem from the top, looking for a centralized solution or equation, rather than from the bottom. In nature, everything works from the bottom up. This means, of course, laying foundations, a step many of us hope to avoid in our impatience for results, in whatever endeavor they embark upon.

That looking for a central top-down equation for a stable self-maintaining biosphere should be an effort doomed to failure, should be self-evident. If a solution were to be found, it could only be a "point" solution, a point in time at which just so many factors were in play: x number of species x', y number of species y', z numbers of species z' – and on and on for all the plant and animal and microbial species involves – and for the number of the human population included – and for the land area and air volumes of the biosphere etc. Now what good is a static solution for elements that can never be in stasis but always jockeying for position, as living ecosystems do?

That biospheres cannot be successfully designed from the top down should be no more surprising than that economies cannot be so designed, much to the chagrin of those who persist in trying. Nature, it seems, is as democratic as economics. Perhaps, we should start from the bottom.

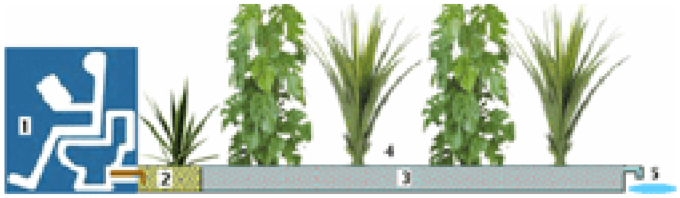
HUMAN OCCUPATION UNITS – THE SPECIAL CASE

In Einstein's theory of relativity, the "special case" was much easier to formulate than the "general theory", preceding it in publication by some nine years, I believe. Similarly, we are here taking a look at one element in the biosphere, but an all-important one, human occupation units. Because these will ever be growing in number, and the volume and mass of the biosphere with it, and because they create the greatest stress on any would-be "equilibrium", the problem occupation units pose is a paramount one. Coming up with an approach that greatly aids towards a "general theory of modular biospherics" would be an important first step.

By **Occupation Unit**, we mean any structure that houses sustained or intermittent human activity of any type that requires a toilet. – living units (homes, apartments, hotel units), places of work (factories, laboratories, offices, schools, stores and shops, etc.), and places of play (theaters, parks, playgrounds, sports facilities, etc.). Why is this important? Because the toilet is the point-source of one very significant demand on the biosphere's ability to recycle and sustain itself. If, as on Earth, we ignore the problem at the source, and shove it off on central water purification facilities, we make the problem and challenge of biospheric stability and self-maintenance enormously more difficult. If, on the other hand, we tackle this problem at the source, in every occupation unit in which there is a toilet, then the aggregate problem needing to be addressed on a centralized or regional basis is greatly reduced.

THE INDOOR GRAYWATER SYSTEM

Several months ago, while convalescing with my shattered leg, I was watching one of our PBS channels on a Sunday afternoon and happened to take in an episode of "New Garden" that told about the unique "Indoor Graywater System" of retired NASA environmental engineer, Bill Wolverton. In the 70s, while working for a NASA that expected to put colonies on the Moon and Mars, Wolverton came up with a system that treats 95% of the problem of human wastes at the source, i.e. within each home or occupation unit. Each toilet feeds a long row of planters that accept the waste as nourishment, and in payment, not only remove 95% of the "pollutants" before the residue water exits to the exterior, but renews and freshens the indoor air, and provides an ambiance of luxuriant greenery. The planter sections adjacent to the toilet are planted with swamp varieties, then come marsh plants, bog plants, finally regular soil plants. The plants are content with low light levels – much less that full sunlight.



Wolverton's system has been operating in his Houston home successfully with no problems for over ~~twenty~~ thirty years. While he invented this to meet then projected NASA needs on a since abandoned space frontier, he continues to work on adapting it to terrestrial needs. For examples, his planter "soil" is extended with "popped" clay pellets that are light weight so that his systems could be used throughout high rise buildings, providing fresh air, the ambiance of greenery, and pre-treating the waste water, without adding undue weight loads, floor by floor.

Wolverton's system runs along the periphery of his home, to make use of ambient direct and indirect sunlight through rows of windows. Artificial light could be used. How could this translate to lunar and Martian or other extra-terrestrial applications?

In the case of surface-burrowed settlements, sunlight can easily be brought in by heliostats or fiber optics, making use of coatings to leave most of the heat outdoors. We have written about such possibilities on several occasions. A modular lunar home, office, lab, shop, or whatever, using filtered dayspan sunlight, and artificial light intermittently through the two week long nightspans, could be combined with Wolverton's indoor graywater system to produce a home or occupation unit in which it would be a delight to live, work, or play: full of sunshine, greenery, fresh air – the perfect counter-point to the alien, barren, sterile, hostile environment out on the surface itself.

In lunar or Martian lavatubes, artificial light, of wavelengths close to that of sunlight, would have to be substituted. On Mars, where sunlight is only half the intensity of that available on the Moon or on Earth, less filtering would be needed for surface-burrowed installations.

What such a system gets us, applied without exception across the board, is considerable. Each occupation unit becomes in effect a functioning cell of the minibiosphere, something much more than an inorganic construct of building materials. Each home or working unit now becomes an organic system as will as an inorganic one (of pressure hull with electricity, temperature controls, and plumbing).

In such a system, we begin to look on the home or occupation unit in a whole new light – not as a foreign intruder in the biosphere that imposes an uncompensated burden, but as a place to live and work that is itself an integral functioning part of the biosphere. The indoor graywater system not only greatly reduces the environmental impact of each occupation unit, it contributes biomass and helps recycle the air, as well as the water, locally.

The home or occupation unit thus becomes a responsible citizen of the mini biosphere. Further, the effect of such a system is to make all homes and occupation units much more delightful places to live – an incalculable plus on the space frontier where so much that mentally and psychologically sustains us on Earth – where we take nature and the biosphere for granted – has to be given up. Here is a living unit with a mission, a mission that works.

As we advertised, this is a "special case" start towards a whole new "modular" approach to biospherics, and approach in which we try to minimize the environmental impact of each element, natural or post-human, by addressing it at the source. This minimizes the residual problems that require regional or central solutions.

The modular approach to biospherics makes sense, because it lends itself to human communities, and their coupled minibiospheres, that can and will grow, naturally, as their economies warrant, addition by addition. Centralized biosphere planning may be narcotically attractive to those who would mega-plan topdown large fixed size settlements such as O'Neill colonies or all-under-one-dome surface cities. But such places, at first underpopulated, briefly populated just right, and then forever after overpopulated are fairy tale dream puffs that cannot deliver the idyllic livable picture postcard environments that artist illustrators have many accepting as the goal.

Modular biospherics is not only a better approach, it is the only approach that can work. Designing frontier homes and occupation units as living EcoCells is a big down payment in the right direction. **<MMM>**

Order "Show # 707 Indoor Graywater System" from New Garden, New Braunfels, Texas for $24.95 – allow six to eight weeks for delivery.

NOTE: In any constructed lunar analog facility (not a pre-built facility into which we have moved) **it makes sense to model structural modularity and biospheric modularity as well.** Doing so will be a research program in itself, over and above any research programs for which the facility is designed or adapted. Finding design problems with modularity and learning to fix them properly should be a primary facility goal. It comes down to "killing as many birds with one stone as possible," in other words the most bang for our buckees. ###

MMM #131 - December 1999

Luna City

The "Developer's" Role:

Putting together a package to attract anchor tenants and a "viable mix" of other clients, splitting costs & burdens, may be just the "accelerant" needed to start Lunar Development in earnest.

By Peter Kokh

Improved Real Estate

Most readers will be aware of the distinction between "improved" and "unimproved" real estate. "Improved" real estate has on site or boundary access to utilities like water, gas, and electric. The lot may or may not have other "improvements" e.g. drainage grading.

"Unimproved" real estate is just raw ground, with no utility access, perhaps not even road access, the kind of stuff Florida an Nevada fly-by-night "developers" want to sell you in the middle of a swamp or desert for a "bargain of a lifetime" price/ Lot's of luck doing anything with it!

All lunar real estate is "unimproved" (and as such, cannot legally be sold)

That does not mean that some locations are not better advantaged than others. Polar sites may have access to water-ice reserves. Highland/Mare Coastal sites have access to both major suites of pre-pulverized (read "pre-mined") regolith. Sites along the Mare Imbrium rim are richer in Potassium and Thorium and KREEP elements. And so on. But these are natural assets. No land on the Moon is man-improved, i.e. with utility access, or with any other kind of location-location-location traffic generating engineered "improvements." This is a daunting, if not intimidating fact facing anyone who has a free enterprise idea for a lunar location. The same can be said of Mars, of course.

Allen Wasser has proposed a lunar "land grant" program to attract lunar development. But perhaps the only ideal customer for such a real estate regime is the "developer" who will go into the prospect site and make improvements that will render it especially attractive to specialized mining, processing, manufacturing, and other types of private enterprise. The first such developer to "improve" a resource-rich well-situated site, may, in the process be founding the first genuine lunar settlement. Even if there is already a scientific outpost on location, without improvements the "settlement" will not come.

The perspective of other interested parties

The mining company, the manufacturing company, the hotel operator, do not want to have to do such unaccustomed preliminary work as setting up power supplies, providing water, building a space port, providing communication relays, etc. If these things were already in place, ready to "plug into" and ready for "hook up", the location would be immensely more attractive. Industrial and commercial enterprise would not have to assume the extra burden of paying for these improvement costs up front, but would merely tap in, and pay a monthly or annual usage charge: utility bills. This drastically cuts their financing costs as well as the time between arrival on the Moon and first returns on investment. It makes their job in closing a deal at a bank that much easier, more realistic.

The Lunar Site Developer's tasks:

(1) Picking a Site for Improvement:

The first task is to analyze candidate sites on the basis of "strengths & weaknesses". The developer should draw up an "Existing Conditions Map." This will include the topography within the area, noting potential obstacles and assets for construction. If there is a science outpost already established, any sharable assets (power, communications, roadways, launch pad) should be noted.

Do assets outweigh liabilities? Are there any "targets of opportunity" such as proximity to uncommon but valuable resources, passages through topographical obstacles such as passes through nearby ridges, natural bridges over nearby rilles? Are there known intact lavatubes in the vicinity? What is the ratio of highland-derived to mare-derived soil in the local regolith? Are there scenic highlights in the area? Is there enough flat terrain for emplacement of large solar arrays? Is there a logical location for a spaceport?

What are the liabilities? Lack of easy access to neighboring areas of the Moon? Uneven terrain? A large number of inconveniently-placed boulders? Rilles or ridges that are not easily negotiated? Such liabilities must be weighed along with assets.

Next the developer needs to brainstorm this mix of assets and come up with a winning strategy to attract enterprises to buy in the development.

(2) The Site Development Plan

Site development plans should work with the lay of the land, develop topography suggested transportation corridors in the vicinity. The location must be picked for the spaceport with adjacent surface warehousing and shipping/receiving areas. Will the spaceport provide loading and unloading equipment so that incoming freighters do not have to carry the extra mass of self-unloading equipment?

Developing the Port Facility will be part of Phase One.

A graded Road Network linking identified Industrial park properties and residential and commercial areas and other special identified use areas must be provided. Easily gradable roadways to important nearby off-location resource-rich areas should be identified and marked. Care must be taken that all such identified sites are easily serviceable both by road and by utility providers.

3) Financial Considerations:

The proposed development must be

- **Market supportable**
- **Physically doable**
- **Financially viable**

To this end, the developer needs to take on "natural partners" in order to subdivide the task and conquer the load. "Natural Partners" will include:

- **Power generation company** (solar &/or nuclear)
- **Oxygen production facility.** Among potentially competing proposals, one that employs processes that produce enriched tailings especially attractive to other potential

manufacturers should be given the nod. Such beneficiated byproducts will help identify and attract other clients.

- **Water production facility**. If the site is not proximate to polar ice fields, and the developer does not wish to co-develop such icefields along with a means of transporting water, or hydrogen produced from it, to the development site, then, if hydrogen produced by heat-scavenging of any and all regolith moved in development of the site does not produce enough to be reacted with locally produced oxygen to meet needs, the balance must be brought from Earth

  The only rational way to meet primary water recovery and waste treatment needs is on the spot where the water is grayed. This will be a burden each tenant-client of the development must assume. The development's shared mini-biosphere must be modular both in construction and in maintenance. This means primary treatment at the source of the problem for both water and air.
- **Mining processing-building component manufacturer** to turn out prefab modular building components to fit customer needs, in order to defray the cost of bringing additional pressurized volume from Earth at much greater expense.

Such a partner building component manufacturer could then enter into a <u>joint venture</u> with the developer to produce "<u>turnkey" factories, warehouses, commercial and residential properties</u> for other clients on the basis of need and request.

Additionally, such a company could construct "<u>hanger sheds</u>" or space-frames constructed of glass composites or steel, covered with plates of the same material, then over-blanketed with regolith to provide "<u>improved" radiation proof "lee vacuum" for easy set up</u> of modular habitat structures, especially less expensive, lighter, cheaper to ship inflatables and hybrid rigid-core inflatables (on the TransHab model). Such hangers or ramadas might be built as rille-spanning vaults: virtual man-made or more exactly, man-restored lavatubes, which is what most sinuous rilles originally were.

Another joint venture would be to provide improved access (graded ramps and elevators) to any buildable <u>lavatubes</u> in the area. Shafts drilled through the lavatube ceiling/roof filled with fiber optic cables, with sun collector on top and light defuser within the lavatube, would be an immensely attractive improvement, as would be a lavatube floor topographic map. No enterprise will buy space within a lavatube, no matter how many theoretical advantages it offers, without solid concrete information, and prepared access and minimal lighting.

Anchor Tenants and other tenants

These "Natural Partners" will be the "anchor" tenants" necessary to attract other partners, clients, and tenants to the development. These latter must be identified with special care to create a viable mix of enterprises that will both provide a healthy balance of diversified exports and meet a major portion of the physical needs of the growing community of people locating in the development to run and operate the various enterprises:

- **Modular housing, other pressurized structures**
- **Furniture and furnishings**
- **Food**
- **Other basic products**

Summary This is a plan in which costs are identified and shared in a manner that makes the development

- **Physically doable**
- **Financially viable**
- **Environmentally compatible**
- **Politically feasible**

It is a prescription for a rational plan to share both equity and debt, to remediate any waste problems, and to share the costs of further improvements useful for all or most parties.

Reader comments and suggestions to further improve this general approach to lunar industrial development are welcome. For contact information, see the box below the front page masthead. **<MMM>**

Relevance to Realization of a Lunar Analog Station Project:

What does all this have to do with an analog research program? Simple: It may be the best way to fund such an operation. In addition to the analog research station proper, other organizations and corporations will be invited to set up their own compatible and related research facilities on the premises. Lease income from them would then finance construction and expansion of the analog research station proper.

In 1987, Mitch Mitchell, a Houston real estate developer, and founder of the unsuccessful "**Lady Base One**" commercial moonbase effort, told us that the way to develop a Mall was to find one or more anchor tenants. If you approach the bank with signed major tenant leases, and have no other funds, the bank will give you the money. Lady Base One failed not because it was poorly planned, but because Mitchell himself went under with the collapse of the Houston real estate market.

MMM #132 - February 2000

"Spinning-up" Frontier Enterprises Profitable for both Earth & Space

By Peter Kokh

The outlook for Space Enterprise would seem to be grim in the wake of the Motorola Iridium bankruptcy. We beg to differ. Yes, investors will be wary of big space enterprise proposals after this major collapse. But how, in truth, would the success of Motorola's effort or of any similar effort help open the space frontier? It would have helped build the market for small payload launchers. Our point is that small satellites and small payload launchers, while they may make money for individuals who may also happen to be interested in opening space as a human frontier, do not in any direct way remove any of the considerable hurdles confronting those who would open space to human beings on any truly non-vicarious, non-virtual level. Small payload CATS, certainly good in itself, is probably not much more than an energy-sucking detour.

We need cheap access to the threshold of space, LEO, for large payloads and for people. AND we need cheap, fast transit "in" space itself. AND, once we can get cheaply and quickly to places where we can tap the vast resources of space, we need the industrial tools to do so. Alas, no one seems to be working on any of this home(planet)work backlog.

The "rocket science" portion of this agenda, we must leave to those with expertise in those areas. What we'd like to talk about is the vast, unexplored potential for making real money now, developing processes and industries to meet the common unexplored resource challenges of good old terra firma Earth and of sundry worlds in space alike.

The considerable "bricks & mortar" portion of Earth's economy, which will never disappear or become irrelevant, has been built entirely upon the tapping of "enriched" resources. It is obvious that it will be cheaper to mine rich veins of ore than more homogenized concentrations of the elements vital to industry. It is obvious, too, that if we are to have self-reliant settlements on space, that they must also be able to "produce" economically, the elements needed for their own Industries. The hitch is, that concentrated ore bodies are a terrestrial asset which we are unlikely to find elsewhere in the solar system. No where else has there been billions of year of geological processing of a world's crust and mantel in the presence of water. Not even on Mars, where such processing may have started only to be nipped in the bud much too early.

Poor Ore Mining Technologies

For accessing necessary resources on the Moon, on Mars, and even on the asteroids (where there is an unsubstantiated widely held belief that concentrated ores may indeed be found), we need to develop mining, beneficiation, and processing technologies that are economical in unenriched deposits. Talk to a mining engineer, and it is likely that if you bring up the subject of "mining the Moon" or Mars, you will be greeted with a contemptuous, condescending put down. No one knows with confidence, how to "produce" metals or other elements from such "poor" ores economically on Industrial production scales. To point to lab-verified pathways of getting oxygen, for example, is not helpful or useful.

We will see no self-reliant resource-using lunar or Martian settlements until we have such technologies. Give us CATS and we will still have nothing! Nor would a political turnaround of unrealistic proportions that would make a lunar or Martian "outpost" a confirmed agenda item change this situation. "Local Industry" beyond a few relatively easy and simple symbolic things, will not be necessary for the token outposts such a political miracle might put on the agenda. We must not assume that if NASA (i.e. Congress) did indeed reverse itself, it would undertake crash programs to develop such technologies.

There is another way, a very mundane way to get the job done. Sadly, space-enthusiasts in general are too much too impatient to sidetrack their efforts to indirect methods that may in fact be much more powerful. These very same "Poor Ore Mining Technologies" would be very useful on Earth, whether we ever do go on to open up the space frontier or not.

Consider Earth's economic geography. The distribution of iron ore, copper, bauxite (aluminum), uranium, and other elements vital to industry has in large measure predetermined which nations have thrived and which have not. Of course, other factors play vital roles: arable fertile soil, access to the sea, forests, and the enterprise quotient of the people.

Poor Ore Mining Technologies would usher a substantial equalizing force into the world economy. Soils everywhere contain abundant aluminum and iron, but not necessarily in the concentrations and in the mineral forms we "know how to" work with cost-effectively. Chemical engineers must blaze new pathways that balance favorably energy inputs, secondary marketable byproducts, and environmental impacts. Concrete specific proposals tailored to the mineralogical circumstances of the various candidate locations need to be made to local or non-local investors and partners that stand to profit. Some of these poor ore mining technologies may have direct or indirect application to the situation we will find on the Moon or Mars or elsewhere. But even where this is not the case, we will be building up a pool of people with a "Young Turk" "can do" attitude to supplant the present unhelpful crowd of "can't do" mining experts.

Molecular technologies under exploration by people like Steve Gillette of the Univ. of Nevada-Reno offer some real revolutionary promise of an end run around present mineral-cracking hurdles. When it comes to producing strategic elements that are much less abundant, like copper, zinc, silver, platinum, gold, etc. where a 1% ore is considered rich, bio-extraction technologies need to be pushed. Without concentrated ore bodies, such elements are often present in only parts per million [ppm], or even parts per billion [ppb]. Bioengineered bacterial cultures may be able to greatly beneficiate or enrich these ambient concentrations. Here on Earth, such technologies would make many nations less dependent on others, less subject to political blackmail.

Novel Building Materials

On the Moon, there are neither forests to supply us with wood, nor petroleum reserves to supply us with chemical feedstocks for the host of synthetic materials to which we are addicted. Even on Mars, with a carbon and nitrogen rich atmosphere and plenty of hydrogen at least in polar ice, bringing such traditional building materials and manufacturing stuffs on line will be a trick. But is the situation any different for scores of countries on Earth that do not have appreciable forests, or who cannot afford to make further inroads into those they still have, and without native oil reserves?

Glass-glass composites have been proposed, and lab-researched, as a promising option for lunar settlement industry. But if we learned to produce a versatile array of glass composite building products and manufacturing stuffs, that could be an immense aid to the economies of countries that must presently import vast quantities of lumber and other products. There would seem to be ample economic incentive for taking this exotic stuff out of the labs, make fortunes in doing so right here on Earth, and in the process develop, debug, and put "on the shelf" a ready-to-go industrial technology that could be a backbone of early lunar and Martian industrial settlements. We developed this idea in more detail in MMM # 16, June 1988.

http://www.moonsociety.org/publications/mmm_papers/glass_composites_paper.htm

But while glass fibers are finding their way into new concrete formulations, no one has bothered to try to earn a buck by taking glass composites themselves beyond the laboratory curiosity stage.

Metal alloys are another area deserving more research. Most pure metals have poor performance characteristics and benefit greatly from inclusion of varying amounts of "alloying" ingredients. Yet it does not seem to dawn on most space supporters that the Moon's considerable "on Paper" wealth in iron, aluminum, magnesium, and titanium – the four "engineering metals" – does not guarantee the easy and economic production of the various alloying elements we are used to using to improve the performance characteristics of each. Steel needs carbon, in poor supply on the Moon. Aluminum alloys generally are rich in copper, a ppb trace on the Moon. Metallurgists who step in to research more "frontier-feasible" alloys which are still "serviceable" may end up producing alloys with considerable marketability here on Earth.

Synthetic Chemical Feedstocks

Mars enthusiasts never tire of pointing out that the ocher planet is richly endowed with the elements that are the basic organic and synthetic building blocks: hydrogen, carbon, and nitrogen (oxygen being taken for granted as ubiquitous). But in fact, most plastics and other synthetic materials are normally not "made from scratch" but from nature-preprocessed cooking ingredients more or less easily refined from oil and other complex petroleum reserves (tar, shale, etc.) We are spoiled. But at the same time, countries not blessed with such reserves are at the economic mercy of those who do have them. If economical "from scratch" methods of meeting such synthetic materials needs could be developed by chemical engineers of the organic-persuasion, this would be of great economic value for many nations. And, as always, the power to equalize is the power to make money.

Bob Zubrin showed the world that methane could be easily made from carbon dioxide by using a totally automated "Sabatier reactor". Apparently, the chemical pathways exist to make other simple organic molecules that could serve as synthetic feedstocks by a similar or adapted sabatier process. Applying such techniques here on Earth might prove profitable. If countries blessed with natural gas, but not with oil reserves per se, could build the equivalent of a petrochemicals industry upon the simpler rudimentary assets of air and natural gas, this could prove a powerful economic equalizer for them. And anything additional to methane that we can learn to produce by these techniques, will also have the happy effect of putting "on the shelf" pre-developed and pre-debugged technologies ready to go on Mars at a much lower cost to the frontier.

In the original oil crisis, research began into using certain plants to produce oils and other petrochemical-like feed stocks. There is money to be made here on Earth by pursuing such agricultural alternatives. And happily, many such advances will be useful to opening the Martian and lunar frontiers. We can learn to be much less dependent on wood, paper, and synthetic organic products. But if we are not to be confined to the constraints of a "New Stone Age" on the space frontier, alternatives to conventional petrochemicals must be developed. We can make money here and now doing so.

"Biospheric" Technologies

Biosphere II was an attempt to come up with a centralized solution for biological life support. Though the specific experiment "succeeded" only by "cheating," in fact we learned much. The only thing that can be dismissed as a failure, is an effort from which we learn nothing. It is much easier to dismiss than to criticize constructively, and when reading such negative reports, one should always discount for the temperament of the reporter.

Beyond Earth, settlements must re-encradle themselves in mini-biospheres that each settlement must establish, grow, and maintain. This will entail the unprecedented challenge of "living immediately downstream and downwind" of oneself. Pioneers in space will not pollute because, unlike us spoiled terrestrials, they cannot "get away with it," putting off pollution problems to the next generation.

But to attempt to do this in a centralized way is just as ineffective as are centralized methods of growing and controlling economies. Modular "market" techniques must be the basis of any effort to establish, grow, and maintain space frontier biospheres. Systems that treat human wastes at the origin and greatly reduce any residual problem that must be handled on a larger scale, are much better suited for non-ivory tower communities of non-static size.

In fact, many people are experimenting with "living machines" and other techniques to integrate plants, air quality maintenance, and waste treatment in unit-sized systems. Such an approach will not only make city-size biospheres a more practical prospect, but will also enable appropriate-size life support systems for spacecraft on long deep-space journeys. We need technologies that are "scalable." In contrast, solutions that address fixed, static size situations are not helpful at all.

The terrestrial profit prospectus of modular biospheric technologies is immense. In the last few decades we have seen the emergence of gargantuan urban complexes in the third world. For the most part, such cities have grown and continue to grow faster than urban utilities can add capacity to keep up with them. The pressure on centralized water treatment facilities is unreal, and the loser is public health. Inexpensive ways to tackle human wastes home by home, unit by unit, that freshen interior air, and provide additional sources of food, would do much to make such monster "blob" cities more livable. There is a market! Let's make money now, and learn how to do space right in the process.

The Gospel of "Spin-up"

The traditional fare of the space faithful is what has long been known as "spin-off." NASA spends hundreds of millions or even billions of dollars developing new materials and technologies that the agency needs for use in space, all at taxpayer expense. Then these technologies are made available to industry at large, providing the usual litany of "benefits for the public" of space research.

"Spin-up" would take the opposite path. Enterprise would brainstorm technologies deemed vital down the road in space for their potential Earth-market applications, so as to make money now. The frosting on the cake is that technologies also needed on the space frontier, would be pre-developed now at the expense of the consumer, rather than the taxpayer (Yes, there is a world of difference in this distinction), and would be ready in time "ready to go" and at relatively low cost to those who will in due course attempt to open the space frontier to genuine self-reliant local resource-using communities beyond Earth's biosphere and atmosphere.

"Spin-up" is a more economical and efficient way to get the research done in a timely fashion. It is the only path not dependent on uncontrollably fickle political tides. And in so far as it is consumer-user financed rather than tax-payer-forced, it is a more moral way to achieve "minority goals" such as ours.

But above all, the "spin-up" route is the only sure way to get the job done. To rely on the traditional route means putting all our eggs under a hen that is not motivated by instinct or any other reliable force to hatch them. We have complained before that those who want to open space by political coercion are abdicating the responsibility for the fulfillment of OUR dreams to those who do not share them, and cannot be made to share them.

If you are blessed with the talent to be an entrepreneur, consider that getting involved in pioneering some of the terrestrially useful technologies needed also in space may do more to guarantee the timely opening of the real space frontier than any amount of seemingly more direct involvement in micro-satellites and micro-launchers.

We do not expect those with electronics and propulsion expertise to get into totally different fields. Each of us must do our thing. Rather, we want to encourage and set loose the untapped talents of others who have not realized that they have a potentially powerful role to play, however indirect. The important thing in opening space is not instant gratification. It is well-targeted patient hard work.

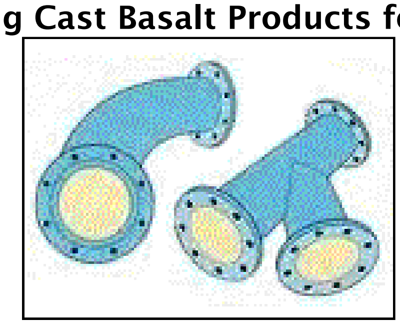
If you are a young person not yet established in a career, consider chemical engineering, poor ore mining technologies, new materials science, "from scratch" synthetics production, bio-extraction technologies, molecular mining technologies, experimental agriculture, and modular environmental systems as rewarding fields in which you can make a difference, both down here and out there.

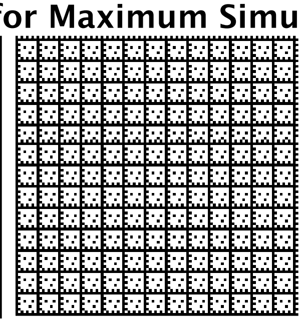
Rocket science can take us to other worlds. It cannot enable us to do anything useful once we get there. Iridium may have failed. It was a detour. There are other, ultimately more powerful and profitable ways to build up to a space frontier economy. Do not waste a moment wallowing in discouragement at recent setbacks. In the end, they won't matter. **<PK>**

NOTE: Encouraging "spin-up" research is a top priority of the Moon Society. It may not advance the day we return to the Moon, but it will surely advance the day when we do something useful on the Moon once we are there - hopefully "as soon as we are there." Even if such research does not produce a technology ready to use on the Moon, if it produces a close analogy thereof, that is helpful. NASA rates technologies on a "readiness scale" of 1 to 10. Too many technologies identified as useful or necessary are at stage 1 or 2. If research done with Moon Society support or in connection with Moon Society analog research center programs is advanced, that will be an achievement of which we can be proud. ###

MMM #135 - May 2000

Cast Basalt: A Startup Industry With Two Great Tricks (Using Cast Basalt Products for Maximum Simulation)





There is a growing, newly reinvented cast basalt industry in Germany, Spain, Britain, and the United States that is producing two types of products that will be very useful in the early lunar settlements: abrasion-resistant pipes & material handling (think regolith-handling) equipment as well as countertops, and decorative wear-resistant floor and wall tiles. These talents make a cast basalt industry a top priority. For more, see below.

Cast Basalt: an Industry Perfect for a Startup Lunar Outpost

By Peter Kokh

Perhaps a decade ago, I read a one-liner in an encyclopedia about a "cast-basalt industry in central Europe." Immediately the need of early Lunan settlements to hit the ground running with appropriate-technology industries came to mind.

Basalt! There is plenty of it on the Moon. The great flat lava flow sheets that fill the maria basins are essentially basalt. The regolith surface of these "Seas" is but meteorite-impact-pulverized basalt.

There is plenty of basalt on Mars as well. The whole Tharsis Uplift area (Arsia Mons, Ascraeus Mons, and Pavonis Mons) is basaltic, as is Olympus Mons. And there are other lava sheet and shield volcano areas on Mars rich in basalt.

The idea of just melting the stuff with a solar concentrator furnace and then pouring it into molds to make useful products seemed a no-brainer. Even if cast basalt had (an assumption) low performance characteristics, there would be plenty of things needing to be made in the Moon settlements for which high performance would not be an issue. Tabletops, planters, paving slabs came to mind.

But for years, I could find nothing more than that teasing one liner. Five years ago, I asked friends in the basalt-rich Pacific Northwest if they knew of any such industry in their area. This did not turn up any new leads. That was then. Today we have the Internet, and I finally returned to the issue and did a simple web search. Voilà!

There is a thriving cast basalt industry here on Earth; and like most "materials" industries these days, it is vigorously reinventing itself. "And the envelope, please!"

Cast Basalt's Abrasion Resistance

Casting basalt in itself is not something new. People began to experiment with it in the 18th century. Industrial manufacturing with this material began in the 1920s when Cast Basalt began to be used as an Abrasion-resistant, Chemical-resistant lining. The material is crushed, and heated until it becomes molten at 1250°C [2280°F], then cast in molds (e.g. tiles), or centrifuged into pipe shapes. The cast items are then heat treated so that the material crystallizes to take on extreme hardness (720 on the Vickers scale where mild steel is 110; 8-9 on the Mohs scale where diamond is 10). The density is 2.9 g/cm3.

Two companies produce abrasion-resistant items for use in material handling (think of handling abrasive regolith moondust on the Moon!): pipes, pipe-fittings, cyclones, conveyor parts -- the list of applications is quite long. Both firms ship worldwide.

- Kalenborn Kalprotect, Vettelschoss, Germany
  http://www.bulk-online.com/YD/Data/Co/09254.htm

This company's trade name for its cast basalt product is ABRESIST "one of the most tried-and-true materials for wear protection. It is high sliding, has a low coefficient of friction, good impact resistance, and very good chemical-resistance. More than 1 million of meters of pipe have been lined by Kalenborn with fused cast basalt. Kalenborn also makes specially resistant products out of other materials such as fused cast carborundum (a form of Alumina, Al_2O_3) and high alumina ceramics, both of which can also be derived from the lunar regolith.

- Antidesgast, S.A. Barcelona, Spain
  http://www.antidesgast.com/english/castbasalt.htm

This company makes a similar line of products under the trade name of Basramite, "the world standard for ash slurry pipe-work at fossil fuel power stations. An all round cost effective, adaptable lining material, extending the life of equipment subject to erosion."

Abrasion-Resistant Materials on the Moon

One of the strongest misgivings frequently expressed about the feasibility of industrial operations on the Moon is the very abrasive and "hard to handle" nature of regolith or moondust. Cast basalt as a material up to the job of handling moving regolith in industrial and construction operations seems a "lunar" solution made in heaven.

Are there any qualifications? The chemical analysis of the basalt used by Kalenborn includes the expected aluminum, silicon, iron, and titanium oxides, but a higher than typical percentage (on the Moon) of manganese, sodium, and potassium oxides. These elements are found on the Moon, however, in parts per thousand, not in parts per hundred.

What we need is a lab test of the performance characteristics of a similarly melted, cast, and annealed small Apollo sample of real lunar mare basalt regolith. This research would make a great thesis for a student majoring in inorganic materials.

An early lunar cast basalt industry producing abrasion-resistant pipes, troughs, and other parts of sundry regolith-handling equipment would seem to take priority over everything else. We have to handle regolith to produce oxygen, to produce iron and steel, to produce aluminum, to produce ceramics, to produce glass. Regolith-handling equipment will be necessary to emplace shielding, to excavate, to build roads. It will be needed to handle regolith being heated to harvest its gas load of hydrogen, helium, nitrogen. Yes, we could use imported items for this purpose. Yes, we could use non-resistant items and keep replacing them as they break down and wear out. But that does not seem to be "logical."

If we are to diversify lunar industry in a logical progression, cast basalt seems the place to start, with an in situ demonstration as task # one.

Cast Basalt Flooring Tiles

Two companies, one in Britain, one in the U.S., use cast basalt to make "durable but decorative" flooring tiles in a variety of shapes.

- Greenbank Terotech Ltd., Derby, UK
  http://www.greenbanktl.demon.co.uk/
- Decorative Cast Basalt Sales, Inc. Webster Springs, WV
  http://www.decorativebasalt.com/

Greenbank Terotech and DCBS import Czech basalt to produce "Volceram [volcanic ceramic] Flooring Tiles" of "natural beauty and practicality." Cast Basalt is now being used extensively by architects and designers for use both as a industrial floor covering in heavy industry and as decorative flooring in commercial, home and retail settings. The skillful 16-21 hour annealing process brings out all the natural beauty that gives the basalt tiles a unique appeal and a natural shine without added glazing.

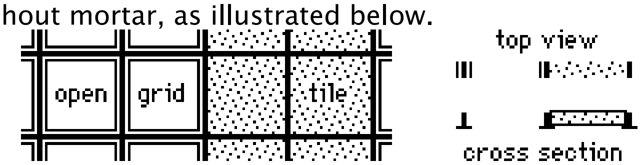
For commercial and industrial use, their hardness ("four times harder than rock, one of the hardest ceramic materials known") and imperviousness to acid and chemical attack make the 25 mm (1") thick tiles very attractive. They "take a beating," retain their appearance, require little maintenance.

This nonporous "industrial strength" tile is nearly nearly indestructible, and chemical-resistant. Yet in the annealing process they acquires a natural beauty that rivals more common ceramic tiles that have to be glazed. This makes them equally perfect for kitchens, bathrooms, halls, patios, etc. Tiles are produced in standard squares, florentine, charlotte, hex and other shapes, and in several sizes to allow a great diversity of floor and patio patterns.

Role of Tiles in Lunar Settlements

Modular habitat structures, will have to have circular vertical cross-sections to distribute the stresses of pressurization equitably, whether their overall shape be that of a sphere, cylinder, or torus. This means a flat floor will have to be constructed over a bottom cavity. this dead space could be used for storage, water reservoirs, utilities, and utility runs, etc. -- an efficiently compacted "basement".

An open-spaced flanged-grid subfloor, of some no rust alloy or of glass composite, could rest on metal, concrete, or glass composite joists. The thick cast basalt tiles could then be set into the grid without mortar, as illustrated below.

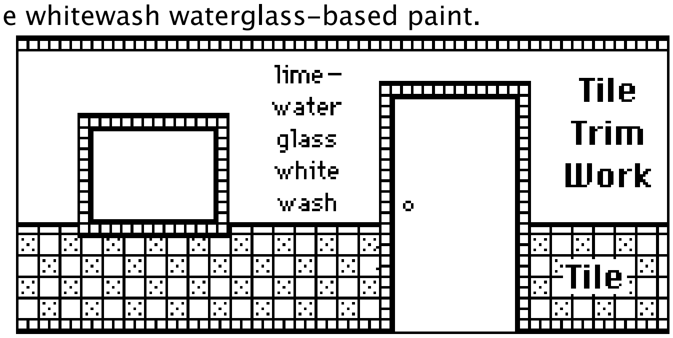


Larger cast basalt tiles could be used for floors of factories, commercial enterprises, schools, etc. And why not also outside, set upon a graded and compacted bed of sieved regolith, to serve as a sort of porch or deck at EVA airlocks, both personalizing such entrances and helping curb import of dust into the interior. One can think of many uses!

Cast Basalt Tiles for Walls and More

The floor tile possibilities and applications seem endless. But cast basalt tiles could be used for more than flooring. Without wood for the customary “woodwork”, plain, textured, and/or decorative tiles could be used, in the role of jamb, casing, baseboard, ceiling cove moldings, even wainscoting. In MMM #76, June, 1994, we suggested the use of ceramic tiles for these applications:

In the illustration below, ceramic tiles are used to provide trim borders. While the seemingly endless variety in color, pattern, and glazing now available on Earth could not easily be produced on the Moon, a variety of hues from the lunar palette (regolith grays, oxide colors, stained glass colors) should be available either unglazed or in soft satin glazes. Tile in contrasting sizes, and coordinated colors and patterns, would make a good companion wall finish, as would simple whitewash waterglass-based paint.



Cast basalt then seems to be the right material with which to kick-start diversified lunar industries. On the Moon, where the regolith particles are quite sharply angular because they’ve never been subject to water- or wind-weathering, we will need a family of abrasion-resistant regolith handling items before we launch our lunar concrete, ceramics, metal alloy, our glass, and glass composite industries. Cast Basalt looms as a cornerstone of lunar industrialization.

Once we have advanced to the processing and manufacturing of these other building materials, we will be able to start providing habitat expansion space from made-on-the Moon materials. Then once again, cast basalt, this time molded into durable and decorative tiles, will help in furnishing the interior spaces of these new “elbow room” modules. Cast basalt will be a cornerstone lunar industry. **<MMM>**

NOTE: Constructed Lunar Analog facilities should use cast basalt tile in as many applications as possible. The idea is to gain experience helpful in construction of actual lunar outposts and settlements.

Visitors will be impressed by this ready-to-go technology that significantly reduces the volume and mass of materials and components that must be brought from Earth. Meanwhile our analog facilities will have a “lunar ambiance” to them. Visitors and personnel alike will grow in confidence that **“yes, we can make ourselves at home on the Moon!”**

MMM #146 - JUNE 2001

URBAN Lofts AND SETTLEMENT STYLE

Note: This article has clues to Lunar-Frontier-appropriate ways to decorate and furnish analog research centers to create a lunar frontier mood.

By Peter Kokh

"Lofty Ideas" is a weekly program (hosted by Katherine Stone) on Home & Garden TV (HGTV), a cable station offered by many cable networks. For those contemplating moving into an "urban loft" in a recycled old factory or warehouse, and for those just intrigued by the idea, this show gives a fascinating look at how a new generation of "urban pioneers" are making themselves very much at home, thank you, in the heart of cities once being abandoned in droves by residents not up to the new frontier challenges. Lofts characteristically retain the relatively high ceilings of floors formerly given to manufacturing and warehousing.

The interior surfaces of outer walls of lofts commonly consist of exposed brick, concrete, concrete block, and other "industrial" materials, unfaced with plaster or drywall or paneling - those more "civilized" interior surfaces all-but-universal in more "traditional" residences: single family homes, town homes, condominiums, apartments, duplex flats, etc. Floors are commonly concrete or refinishable wood plank with a healthy hint of industrial wear & tear character worked in.

As purchased by their new occupants, lofts also most commonly boast exposed heating ductwork, plumbing pipes, and electrical wiring. And most new loft dwellers choose to keep it that way. To this shell which most lovingly accept, they may or may not add dividing walls (seldom full height), partial step up floors (a loft within a loft, e.g. for a bedroom) window and floor treatments and furniture and accessories. The extraordinary amount of highly personal creativity demonstrated in the half hour episodes of "Lofty Ideas" week after week is utterly amazing. For loft-aficionados, this is where it's at.

What has all this to do with future frontier settlements on the Moon? It occurs to me, that some of the "styles" we see emerging in this new residential medium, will also prove to be the most appropriate, the most efficient, and the most economical, once we are manufacturing modular housing shells on the Moon, for pioneers to turn into "home sweet home" oases in this magnificently desolate new setting. The reason is simple. Adopting the "as is" inner surfaces left by construction of pressure hull habitat modules removes the labor-intensive burden of giving them a faux finish, e.g. plaster or wall board plus paint or paper or paneling. Settlers need to save free time for where it counts. Let's take a look

The Shell (or hull)

The Moon is well-endowed with the all four of the so-called engineering metals: iron (steel), Aluminum, magnesium, and titanium. Metal alloy pressure hull modules are a primary option for the lunar architect and module manufacturer. Lunar concrete, reinforced with steel rebar or glass fibers to give it strength under tension is certainly another. Glass fiberglass matrix composites are a third. Surface treatment options available to the architect depend both on the character of the material, and on the manner in which the pressure hull is fabricated.

If the hull material is poured wet, and/or hot, into a prepared mold, its surfaces will take on the character of the surfaces of the mold into which it comes in contact and by which it is constrained. Molds can be smooth, textured, embossed, or carved to create surfaces with special design characters.

In the case of concrete, if coarse aggregate is used, and the surface of the cured cement abraded somewhat, the aggregate with all the character and variation it may have, is brought to the surface. If this is not done, character can be imparted by the mold itself. We have all seen the clear telltale imprint of plywood forms on poured concrete walls. If the form, of whatever material it may be, is given deliberate texture or pattern -- and the possibilities are virtually endless -- that texture or pattern will be transferred to the surface of the cured concrete.

This option can be used to endow surfaces with random or repetitive design patterns. I have seen a basement wall of poured concrete that looks like brick, thanks to the pattern worked into the pouring forms. With two inches of styrofoam bonded to the outside, the result is an instant “recroom-worthy” surface. Surfaces with leaf patterns, coarse cross sawn wood patterns, almost any kind of pattern is possible with concrete. Colored concrete sidewalk pavers with embossed patterns are also appearing. As are concrete shingles that look like cedar shakes. It seems that concrete can mimic almost anything.

We can speculate how we might fabricate habitat pressure hulls from glass composites, but until we have proven, debugged methods and options, we can only guess at the design possibilities. That we can texture the surface seems likely. We may be able to etch it, applying resists and sandblasting. We might be able to color, even grain glass composites, by embedding colored glass fibers in either a random or “raked” pattern in a clear glass matrix.

Metal plate and sheet can easily be embossed, but perhaps only coarse pattern can be imparted to poured metal by mold forms. These uncertainties aside, the use of mold forms in habitat module fabrication and manufacture are a primary opportunity for textural choices with the goal being to use the resulting interior surface as decor in itself, not as a substrate for some hiding faux surface treatment.

Construction-processed surfaces might then subsequently have any mold imparted patterns or textures enhanced by several means.

- **wall washer lighting** can enhance textural shadow patterns
- **colored bulbs or colored glass diffusers** can wash textured surfaces with color tints.
- **whitewashes** based on lime (CaO) or Titanium Dioxide should soon be available to beat the concrete gray blahs.
- **“stains” using metal oxide pigments** might be used to highlight textural surfaces in directional patterns, depending on means of application

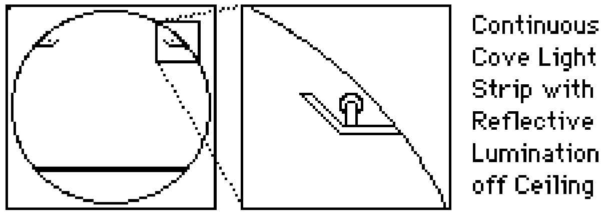
What we are talking about is principally the interior surfaces of the exterior pressure hull. In one-story modules, that includes the ceiling, which, if of concrete, may commonly be whitewashed.

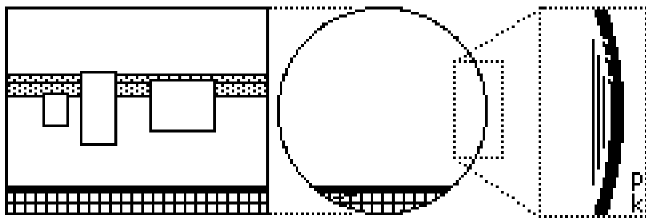
Our point is that here is a method of instant “direct decor” in which the architect and purchaser have many options to choose from, simply by allowing the character (the “grain” as it were) of the chosen hull material to give an “encore performance.” By choosing any of these direct decor options, the lunar habitat is finished and ready for occupancy much sooner. Then any sweat equity required or volunteered on the part of the frontier homesteader can be postponed, saved for other things and features to be added as time, energy, and funds are available.

On the Moon we cannot afford to have housing units “under construction for months.” The ideal ground-breaking to occupancy-ready interval should be much shorter, week at most, but with the ideal of “in one day” ever the target. Construction in vacuum is a risk-involving activity and we want to do it in as manhour-light a manner as possible, reserving man-hour-intense activities for optional interior customizing at leisure.

Hull Details

“Trimwork” (akin to our “woodwork”), if any is desired on interior hull surfaces, can be of sheet metal, ceramic tile, or glass composite, depending on the hull material (alloy, concrete, glass composite.) This trimwork can be of colors and shadings that blend in, compliment, or contrast with the substrate. Glass and ceramic glazes are made with metal oxide pigments, many or which are lunar-sourceable. Steel trim could be rust-finished or even stainless.





Built-in hanging grooves for on-the-wall items

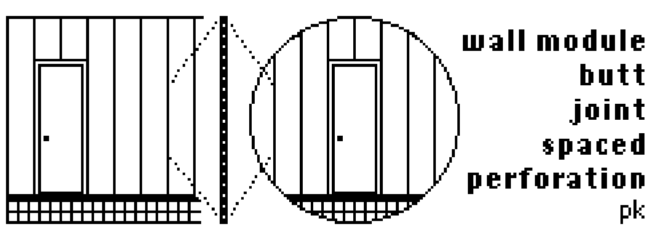
In addition to surface texture, pattern and detail, functional features can be built into exterior hulls, such as coves to hold ceiling wash lighting, chases for electrical wiring or conduit, and well-placed purchase points for hanging shelving, wall art, etc. The built-in features also serve to shorten the construction to occupancy wait time. Even bench or banquette style seating can be provided as desired.

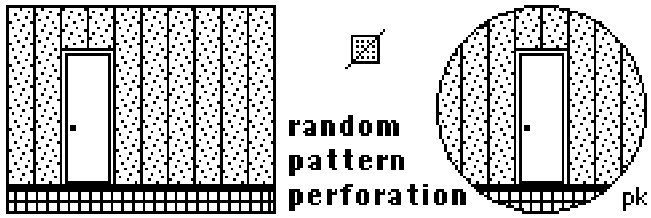
Interior Wall and Floor Stuffs

Interior walls and surfaces of interior ceilings (i.e. another floor above) are also likely to be manufactured, fabricated, or constructed with materials that can provide an acceptable surface. Logical interior wall options are:

- **modular half meter sections** with steel frames covered with steel panels: finished through a controlled rusting process to introduce relief from gray monochromes, or of stainless steel. They can be variously textured or embossed
- **custom built on site** using steel studs and Duroc™ panels (a familiar item: half-inch thick fiberglass-faced concrete sandwiches): the Duroc surface can be accepted as honest direct decor, possibly whitewashed, or stain-washed. Trimwork and/or wainscoting can be of ceramic tile.
- **glass block walls** - transparent, translucent, or opaque; of clear glass, frosted or sandblasted, or crude formula lunar glass of gray-black tones.
- **steel framing “upholstered”** with stretched fiberglass fabric over foil-faced fiberglass batting

Interior walls too, even though made of harder materials than we are accustomed to using on Earth, can be pre-fitted with purchase points for hanging wall art and shelving. Consider this:



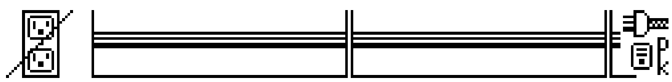


We wrote about wall options in MMM #76, June '94, p. 4. "Inside Mare Manor: Interior Walls."

Exposed Ductwork

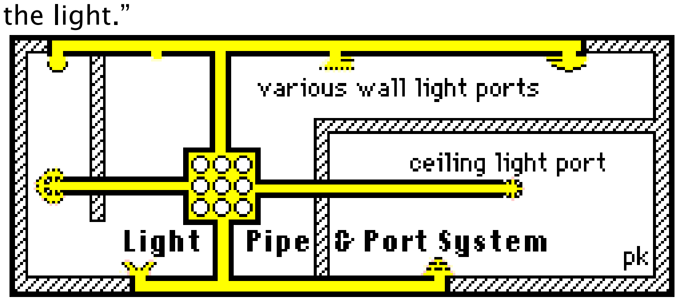
Another commonplace in urban lofts are exposed ductwork for heating and air-conditioning. Using systems to decorate has become a flagship feature of the "Industrial" style for many public buildings in the past two decades. Ductwork can be designed to have a simple comeliness of its own, adding interest, not ugliness. The original motivator, of course, is the substantial cost savings of not having to "hide" such systems with false ceilings.

The same is often true of conduit carrying electricity throughout the loft or building. With a little fore-thought, the elements can be enhanced for eye appeal without compromising utility, and at nominal extra cost. Routing such systems offers another opportunity for input from the interior space designer. Slight changes of placement or routing cost little. All one needs to do is pay attention to the decor effects of various options – an attention that is not ordinarily given, but can be.



Light Pipes

On the Moon, where we have a chance to start fresh on many fronts, one significant opportunity to do things differently is lighting. Light pipe technology has been advancing steadily. Light pipes are passive systems that deliver light efficiently from concentrated sources (solar concentrators, sulfur lamps, etc.) throughout interior spaces, in both straight runs and around corners, to places where the light is needed. Light ports in the pipe/duct system can then be decoratively enhanced by the choice of diffuser or lampshade analog. They can also be shuttered to "turn off the light."



We reported on light pipes in MMM #66 p.7 June '93, "Let There Be Light: light delivery systems for lunar settlements need to be rethought", and on Sulfur Bulb technology in MMM #36 JUN 2000 p 3. "Nightspan Lighting: Sulfur Lamps & Light Pipes."

Flooring

Pressure Hulls have to have curved surfaces to avoid stress points along surface "intersections" that would be prone to fracture, and hence pressure loss. Thus for most hull designs, flat flooring has to be added later. So we will not discuss that here except to mention some of the obvious choices: cast basalt tiles, ceramic tile, glass-composite sheets, concrete pavers, and embossed steel sheeting.

A Frontier Primary Color Palette

The reliance on "direct decor" – letting the honest character of construction materials provide the setting for added furniture, furnishings, and accessories will result in a naturally lunar, frontier palette of hues, shades, and tones to be played to in monochrome, complementary, or opposite suites. Concrete gray tones can be easily “tinted” by washing them with colored light (bulbs, diffusers, etc.). Eventually, as locally produced sodium silicate and metal oxide pigment powders are produced, applied color “washes” may become an option. Lime or titanium dioxide “whitewash” will surely be the first of these to appear and become popular, on walls and ceilings alike. Metal oxide pigment stains might be used to give highlights to the texture relief.

Tile “trimwork” can accent the concrete, with glaze colors that play to or enhance the natural lunar grays. Steel and aluminum silvers, rust-cured steels or rust-cured steel trimwork can also add accent. Enamels for steels may not come soon.

Natural raw frontier glass will be of variegated moontones ranging from blacker to lighter. If regolith is routinely sifted for glass spherules that are then automatically sorted for color, crude glass with orange and green tones should soon be available.

Mirrors hung on moontone walls can also capture and “import” the brighter colors of added furnishings. Lamp shades, ceramic glazed items, art glass, and, of course, abundant foliage and flowers can add all the “pop and punch” colors one could want. The “industrial” “loft-like” host decor of lunar frontier habitat modules need not be drab. The great creativity and amazing variety of ways in which our urban loft dwellers make spaces with industrial histories very homelike gives us not only insight into the future of lunar frontier homes, but confidence.

It’s a wrap ! - of course, those who can afford it will find it chic, appropriately pretentious, to bury the construction-processed surfaces with faux facade treatments of one sort or another. But our purpose here is to show what an “everyman’s frontier decor” might be like. <**MMM/**>

MMM #183 - MARCH 2005

The Mars Desert Research Station (MDRS) in Utah

The MMM editor spent two weeks in February (and another two, the following April 2006 as Crew Commander) at this remarkable facility in Utah. Below and elsewhere in this issue, he tells about the achievements, the frustrations, the opportunities. Most importantly, he lays out the case for other organizations to support the analog station effort in various ways. Much of what we discover in this effort will apply to Lunar operations as well.

A Broad-Based Effort to Expand the Scope of the Analog Research Station Program

By Peter Kokh, Editor of Moon Miners’ Manifesto
Life Member, the National Space Society
Former President, the Moon Society,
Member, the Mars Society,

Member MDRS Crew #34, The Junk Yard Wars Refit Crew

Both the Mars Arctic and Mars Desert Research Stations (FMARS and MDRS, respectively) established by the Mars Society, have been working magnificently from the beginning to create environments from which we could learn better field exploration techniques. We have been learning what techniques and what equipment, that look good on paper, work in the field, and what does not.

By the simple means of having all crew members wear "space suits" whenever they go outside the Hab, the illusion that they are on Mars thus created is strong enough to induce the crew members' wholehearted participation in the experiments they conduct. Good choice of host terrain with minimal plant life, suggestive in coloration and land forms of what we expect to find on Mars certainly helps. The lack of phone and cell phone service as well as of TV all reinforce the illusion. Understandably, there is no effort to impose 6-40 minute time delays on Internet downloads and uploads (although that would be the case on Mars!) but a token 3 minute delay is worked into communications between the Hab and Mission Support in Denver or Ann Arbor.

We have learned that ATVs, "unpressurized rovers" not unlike the Apollo Moon Rovers used on A15, 16, and 17 are essential: rather than be replaced by larger, faster, longer ranging vehicles with pressurized cabins, they are necessary to accompany the later, much as in a naval fleet, a lot of specialized smaller craft accompany the battleship. Taking it a step further, we have learned that small tele-operated robotic rovers operating on tether leashes from the ATVs or PEVs are enormously helpful. They can scamper up hills and down valleys nonnegotiable by the wheeled ATVs and PEVs to greatly enhance the exploration and examination of terrain traversed.

We have learned what instruments are helpful in exploration: GPS units, and software that tells the explorer what route from A to Z will get him to Z in the least time with the least exertion and the least risk. That is something that is not easily determined by visual clues from point A alone. We've experimented with different types of tools to do geological field work as well as biological tools to look for evidence of microbial life.

While much was learned about space suit design and performance in the Apollo experience, we've learned a few more things on Devon Island and in SC Utah. The ingeniously designed mock-up EVA suits have brought to light a number of design challenges that must be addressed if our pioneers are to function as efficiently as possible.

We have discovered a few things about the human life support system as well, for example that we only need a third as much water ration per person per day for hygiene maintenance as NASA paper studies had supposed.

We have learned how to better organize daily work schedules, how best to divide the workload, how best to combine work with attention to personal needs and inter personal relations.

In short, the Analog Mars program has helped uncover lessons that never would have been learned on paper. We are helping to contribute to the success of future efforts by NASA and other space agencies.

These efforts have also attracted much publicity, resulting in increased anticipation and support on the part of the public and the media. The Mars Society's strategy has been two-pronged from the outset.

How can we do more, and on a broader front?

At this point, we need to take a look at some serious questions:

Question: What can we do at MDRS to learn more without tearing down the present hab and building a new one?

Question: What useful simulations can be done in settings that are not "Analog Mars," but which are more easily supported logistically?

Question: What useful work can be done at MDRS – and elsewhere – by other groups who share the goal of preparing the way for humans to establish permanent presence on Mars and other worlds beyond Earth? The past two decades have been ones marked by turf-protectionism, dare we say "turf-retentiveness," on the part of separate space enthusiast organizations and their leaders. Looking forward to a 21st Century marked more by collaboration, what can we all pitch in to help achieve in the area of outpost and outpost activity simulations?

Lessons from a working visit to MDRS

Last August, we announced a new Moon Society project to "rent" MDRS for a two week period in order to conduct a number of Lunar Outpost activity simulations. At first glance, there seems to be a good number of useful things we could do in south central Utah, some relevant to lunar outposts only, others relevant to outposts on both Moon and Mars. But without first hand knowledge of the facility, it would be difficult to plan an effective "Moon Mission." It was important to go see for myself. Having long been a Mars Society member as well, I applied as a "crew volunteer," and with the help of long time friend Ben Huset of the Minnesota chapter, we both secured a spot on Crew #34. This was especially fortunate, as this crew would not be a simulations and research crew, but a "refit" crew: our mission was to replace the Hab's wiring, plumbing, and heating systems -- bring them up to code and solving some major problems: repeated pipe freezing, uneven heating, etc. Crew #34 was an opportunity to learn how MDRS worked from the inside-out as assistant electrician and carpenter.

Necessarily designed as inexpensively as possible, and assembled as quick as possible to meet season use and publicity timelines, MDRS suffers as a result in some areas:

• **We cannot simulate a closed life cycle environment at MDRS**, even with a much more thorough biospherics module than the present GreenHab which recycles gray water from sinks and showers for use in flushing the toilet -- MDRS leaks like a sieve. It is not a sealed structure, and it would be cheaper to build a new one than to seal it effectively.

Air recycling and thermal management are not the only two casualties of the leaky hab. Dust control is all but impossible. Mouse control is a lost cause with a two inch gap under both front and rear hatch doors, besides oversize holes for pipes and conduits passing through the hab wall, and poorly sealed, uncaulked portholes, and a loose laying plexiglass door over the roof emergency exit hatch that flaps in the wind.

• **We cannot easily conduct Adequate Shielding Exercises** - First, the site is owned by BLM, the U.S. Bureau of Land Management, and our conditions of use require us to tread lightly on the site. Moving around large volumes of soil might not fly. Even should we get a "variance," shielding the Hab would be a daunting proposition. It is too tall. Sandbagging the Hab dome alone would be insufficient and futile. A spread out, one story "Mars Ranch" structure, set on or into the local surface, would be much more practical to shield.

And this situation is regrettable. While in Utah, we are not subject to the same cosmic radiation and solar flare threats from which Mars' explorers and pioneers must seek shelter, our "Field Season" is unnecessarily shortened by the impracticalness of cooling the MDRS Hab from the fierce summer desert heat.

On the Moon and Mars as well as in Utah, the principal co-benefit of shielding is thermal equilibrium. Face it, Mars' surface is as cold, or colder than Antarctica. Yet a few meters down, the soil temperature is the same year around, though the equilibrium temperature there is much lower than it is on Earth or on the Moon. Thermal equilibrium is the principal design benefit of underground housing on Earth. Soil-sheltered habitats simply make sense, however uninteresting they may look to the photographer or artist. And we do need to simulate this, to uncover design challenges that are surely lurking. For in fact, while we do have considerable experience from building earth-sheltered homes here on Earth, they are not designed to the same set of constraints we will face on the dry Moon or on wet Mars.

• **The Hab has been designed for expansion.**

The Mars Desert Research Station Hab structure was designed with two EVA hatches. The rear one has been used principally for quick access to the generator and diesel fuel station, to the propane tank, and to the water tank. But from the outset, this extra exit was looked on as a point of future expansion. Now the time may have come to take a new look at this option -- for on Crew #34, all these utilities have been relocated to a new area, shielded from the Hab by a thirty foot hill. That barrier provides quiet (the generator is a major noise contributor, day and night) and safety: should any of the fuel sources ever catch fire or explode, all of them would in a chain reaction -- the hill provides safety from the fireball that would result. Note: Crews 33 and 34 also installed a superior grounding system, a real feat in the low-conductivity soil, following the ideas and methods, .and using the tools developed by a young volunteer from Caracas, Venezuela, Gregorio Drayer, under his supervision.)

Expansion modules, hard-shelled or inflatable, if designed in one-floor or "ranch" fashion, might support emplacement of removable (sandbagged) soil shielding. This would provide a test of the thermal-equilibrium benefits and a basis for redesigning future analog Habs.

The Hab now supports some activities that get in the way of one another. While it is important to design multi-function space that will see more round-the-clock use, it is equally important that these multi functions not interfere with one another. My choice for first candidate to move to new added expansion space is the workshop-tool-shop-fabrication area which could include an area in which to experiment with making things out of the local soil (even if it is chemically or mineralogically a poor analog of soils on Mars.) These activities are currently hosted by the Lab Science area.

A real Greenhouse engaged in food production as well as gray and black water recycling should be next. The principal impediment to growing food at MDRS is that the site is occupied only seasonally, primarily because of the desert summer heat, which could be managed by living undersoil. But that facility still could not recycle the air of the leaky Hab (one reason winter season heating bills are so high.) It must be added, however, that even if we overcame the heat problem in this fashion, the volunteer supply is not great enough currently to handle year around operations, unless skeletal crews are used in the summer season..

What else needs to be simulated?

● **Simulating Human Crew Systems:** No matter how good our equipment is, no matter how well we have developed our procedures and processes, the most important system of all, because it is central to everything else, has been simulated only on a hit and miss basis, with the result that lessons learned, while valuable, are trivial in contrast to the need. We must not downplay simulation of human crew systems.

● **Simulating the Lunar Frontier Diet:** There has, in fact, been a hit and miss effort to simulate the kind of diet Mars Pioneers will surely face: freeze dried foodstuffs from Earth rehydrated with water from Mars, supplemented occasionally by fresh produce from the garden, and possibly by not too frequent treats of Talapia filets: Talapia are a species of fish which thrive reasonably well in gray water systems integrated with greenhouse food production. The problem at MDRS is that individual crew members vary greatly in their willingness to go that far in simulating the Mars experience. All too frequently, their shopping trips in Salt Lake City where they gather to begin their mission, end up with a lot of menu-buster treats. The pioneers on Mars will have no such luxury.

● **Simulating Frontier Recreation, Art, and Hobby Options:** In after supper free time, if there is any, crew members at MDRS can read, play games, watch DVDs. In fact most are busy at their laptops. Simulating realistic frontier recreation and hobbies is something that can happen at MDRS but seems to have been given no real emphasis. We contributed a Mars analog version of the age old African classic game known by various names from tribe to tribe, and most commonly in the west as Mancala or Oware. The board was crafted from wood, but painted to simulate Martian ceramics. A "pit and pebble" class game (rated as one of the nine best of all time in strategy), our version has been dubbed Craters & Blueberries. We also took a look at Scrap and Trash generated at MDRS. On the future frontiers, such humble materials will jump start frontier arts and crafts.

● **Simulating Ergonomic Alternatives:** Ergonomics is important for good crew morale and efficient operations. A major opportunity was missed by the decision, in designing MDRS' interior, to copy the layout of the FMARS arctic facility. A clean slate redesign, finding new solutions to the same design constraints, would have yielded useful ergonomic information, comparing experiences at the two stations. The interior of the Euro-MARS station slated for Iceland, has indeed been redesigned from scratch, and whether it has the blessing of the Society's founder or not is immaterial.

You can not learn if you don't vary the conditions of the experiment. It is that simple.

Happily, the Aussies are proposing a Hab that is not of the double tuna-can stack variety, but going back to an earlier design for a more horizontal, easier to shield structure.

• **Hab Interior Ergonomics:** Getting back to my recent visit, I had hoped to get input from my fellow crew members on what they would change about MDRS, if they had a magic wand: what areas could function better by mutual isolation, which by being collocated more closely. What functions of common areas would be better served by having a dedicated space to themselves? What activities, not supported by the current design should be worked into any proposed expansion. Alas, we seldom had free time after dinner. We were always behind in our refit schedule and worked often into the wee hours before hitting the sack. I was able to get only minimal feedback.

We hope to develop a questionnaire that future crew mission commanders can circulate on a voluntary basis, and thus get a wide spectrum of input. And by also circulating feedback forms to past crew members, we may get some return. Unfortunately, such debriefing will suffer from the staleness of memories. But it is also possible that some former crew members will have better digested their experiences and be able to pick out and identify things that bothered or irritated them that they might not have been able to "put their finger on" in a classical "fresh from experience" debriefing. Both fresh and digested experiences are helpful.

At MDRS, the interior of the Hab is very poorly simulated, along with living conditions. In the recent "refit" mission, we had no time to attend to even a partial facelift. There are materials other than wood and drywall that would simulate likely interiors at not too much extra expense. Right now, that is not a priority, though the money could be easily raised separately.

• **Acoustics:** The individual staterooms share the same floor as the wardroom common space: without any acoustic insulation, this is a problem for those early to bed and early to rise. Earplugs are one way to cope. But this is a problem that could have been lessened with good design and involvement of an acoustics specialist. In fact, the Hab is a very noisy environment, and that can only dampen performance over the long haul. Relocation of the generator behind Engineering Hill has removed offender # one, however.

• **Logistics is important.** For MDRS, Salt Lake City, the nearest major air hub some 240 road-miles to the north, serves as the staging point. (Denver and Las Vegas are both 400 miles distant. Grand Junction, CO at 160 miles is only a regional airport with higher airfares.) From Hanksville, the nearest hardware stores are 115, 160, 188 miles distant. Now remoteness from urban areas does have its advantages. It helps set the scene psychologically. And the MDRS clear moonless nights offer an awesomely star-spangled, Milky Way dominated gasp of what it must be like to be suspended in space, or on Mars or the farside of the Moon.

• **Dust Control:** A determined effort to identify all the holes and gaps in the Hab outer wall and bottom floor should be made, and a master plan developed to seal them with durable materials that blend in. A stop can be built into the hatch thresholds that will do away with the 2 inch gap along the floor that remains when the hatch is closed. And above all, let's put out the call for a donor to cover the need of fabricating new porches and steps and apron approaches to the steps out of grating. When it rains even a little, the plant-free surface turns to mud, and with only wood and plywood surfaces guarding the entryways, transport of mud inside is guaranteed. That the Society does not have enough money in its general funds is no excuse. If it's worth doing, and it is, we must ask for dedicated funds, special donations. People give more when they know it is going to something specific the importance of which they can appreciate. The porches and steps are a prime example of a false economy,

Maintaining "Sims" (doing all outside activity in EVA spacesuits; staying on Analog Mars): Remoteness of hardware supplies from lumber to electrical, plumbing, and water supply needs was a major challenge for our "refit" mission. But simulation and research missions are designed to be more self-sufficient. However, the crew members on hand may be minimally capable of meeting various equipment and other emergencies and reliance on intervention from nearby Hanksville is openly accepted.

We are making no progress in simulating Real Lunar Frontier Isolation from Earth.

MDRS is dependent on regular fuel supplies from outside: diesel fuel for the generator; propane for heating and cooking; and water. In short, we have not yet been able to upgrade MDRS to the point where we are generating our own fuels, Marslike, from the atmosphere, or tapping local water reserves underground. We use only some solar energy, for the GreenHab. We also depend on outside services to repair the ATVs, an all too frequent need. On Mars, the outpost will have to be equipped for such emergencies, and have trained personnel among the crew consist.

That we pretend that Hanksville is a Mars Orbiting Station, and that Salt Lake City is Mars' moon Phobos, does little to simulate real Mars emergencies and real lack of options. There has been some hit and miss effort to document "out of Sims" activities. To minimize these occurrences will take a many vectored approach. And in preparation for developing such portfolio of strategies we will need more consistent, more detailed documentation, both on the part of the Crew Commanders and on the part of our off-site support people.

These many improvements can only be phased in, one at a time. The important thing is to realize that we must make progress in that direction,

Place for a lower level of "Sims"

Not everything has to be harder. On the Moon itself, if all the things that needed frequent and regular attention and access where placed under a shielded, but unpressurized canopy or ramada, those attending to this area could wear lighter weight, more user-friendly pressure suits. At MDRS, those attending to the generator or other outside utility sources are supposed to wear full EVA suits. One of the personal projects I chose for my time at MDRS was to investigate the practicality of a demonstration of this system in Utah. Now that all the utilities have been relocated behind a noise-, fire-, and blast-buffering hill, we at MDRS could assume that they are under such a canopy, and wear designated lighter overalls and a special gas mask to simulate the lighter suit. A study of the ergonomic benefits recorded would give feedback on the value of such an innovation. Walk areas thus protected could be marked with simple color-coded poles, for fabric pretend canopies would not last long in our Earth desert winds.

What can be done elsewhere to compliment the learning exercises at MDRS and FMARS?

The Moon Society looks forward to the day when it can establish its own analog research station in terrestrial locations more suggestive of the Moon's surface than that of Mars. But that is not our concern here. What can de done elsewhere, in any type of host terrain (even verdant farmscapes and urban cityscapes) that will help us prepare for pioneering Mars (and the Moon)? While exploring the surfaces of other worlds, and examining their chemical and mineralogical makeup may be the most obvious, visible, and high profile aspect of early outpost activity, it is only the above-horizon tip of a largely hidden iceberg. Far more basic will be the successful operation of the systems that sustain the pioneers: life support, including food production and recycling of water, air, and both human and agricultural biomass waste. And the systems that maintain both the physiological and psychological health of the pioneer teams. None of this depends essentially on the host terrain, at least not in ways that require some sort of visible match.

Life support, medical systems, human factors such as ergonomics, food menus, etc. -- all these can be simulated anywhere it is convenient to do so. Logistics: where do the principal investigators live? or where is it convenient for them to visit habitually Where are clusters of volunteers?

These questions are important. In Utah, only one person maintains real continuing presence to help ensure some degree of continuity between crews. Don Foutz, a local resident of Hanksville and a strong supporter of the Mars Society's analog hab program is on call, ready to train incoming crews, trouble shoot problems with the balky generators, and fickle Internet uplinks, and so on. We are fortunate to have Don. Without him, the Hanksville-based facility would have collapsed after the first season, if indeed it lasted that long. Of extreme importance are both continuity in expertise and availability of critical personal who take ownership of ongoing programs that cannot be adequately managed from Mission Support in Denver.

It would be difficult to run a more ambitious Greenhouse Food Production and Water Recycling system without a principal investigator living nearby. That such a facility serves a crew of six persons engaged in exploring an analog Mars landscape is irrelevant. Whether this be a program managed by staff at some university or college or by a dedicated individual, continuity and dedication both demand that the site be convenient, on a weekly or more frequent basis by the person accepting responsibility, and responsible for the design elements, and with authority to make changes. For "load," such a system could be linked to any living space regularly occupied by the desired number of persons, six or whatever. There is no need for the persons imposing the load (food needs, waste generation) to be involved with Mars simulation activities of any kind, unless some such can be happily collocated.

A medical system designed to meet all reasonably expectable emergencies for a group of six (or whatever) adults could be tested in any isolated small community where access to medical services is extremely limited. Small Eskimo or Inuit villages might do, although most are too easily accessible, these days, by airplane or helicopter.

MDRS is both blessed and handicapped by its remoteness. But the Moon will be significantly more remote. All the more reason to go beyond field exploration techniques to pre-develop all the systems that will be needed to survive on the Moon long term, without recourse to rescue or resupply.

At sites near stable clusters of dedicated individuals, simulations can be run by long term crews Other groups, inside and outside the Mars Society, can conduct exercises elsewhere that complement work at MDRS:

- thermal management through soil (regolith) shielding
- identify and develop optimum models of outpost expansion and develop expansion architectures
- develop more tightly closed life support systems that recycle air, water and waste to provide fresh food
- develop realistic food-nutrition-menu systems that expand phase by phase in diversity and satisfaction
- experiment with different interior layouts to determine their ergonomic pluses and minuses
- develop crew recreation, arts & crafts, gaming, and hobby opportunities for greater crew morale

Fringe Benefits of Multiple Networked Simulation Sites

Distributing the simulation workload will allow the tapping of personnel and organizational resources not now accessible to the Mars Society's Analog Mars Program. That benefit is considerable: more talent, more money, more publicity. This united effort will not be lost on the public nor on Congress which will soon pick up on the signal that "those feuding space groups" finally have their act together.

Geographic dispersal of the effort will also model the development of a multisite, multi-settlement Lunar Frontier Economy. That too will help science popularizers sketch out just how a first human mission will evolve beyond flags and footprints into a second human home world.

There are already strong dedicated concentrations of volunteers in the form of focused chapters within the Mars Society, the National Space Society, and the Moon Society that could undertake some useful bite-size project, however humble, in support of the broader effort. SEDS (Students for the Exploration & Development of Space), and other groups might be willing to help. We have grounds enough to launch an Analog Moon "Extension" Program.

Benefits from many simulation exercises will apply with minor adaptations to both Moon and Mars. Others will apply only to one or the other. We call on other Space Organizations to endorse an expanded Analog Simulations Program and seek appropriate ways to contribute to it. This will grow chapters as well as public support. <PK/MMM>.

"Destiny is not a matter of chance; but a matter of choice. It is not a thing to be waited for, it is a thing to be achieved." **William Jennings Bryant**

MDRS Scrap & Trash vs. Spirit & Opportunity

Report by Peter Kokh, Wisconsin Mars Society
MDRS Crew #34, the Junk Yard Wars Refit Crew

Scrap & Trash at MDRS

One of the items on my list of things to do at the Mars Desert Research Station was to take a look at any scrap piles that may be on the premises and also at what was in the everyday trash. I found the area known as Antarctica or the Engineering Area just south of the Hab, hidden behind a pair of natural mounds both from the Hab and its access road. There I found discarded PVC pipe and fittings (from the old GreenHab), some copper, aluminum and steel; also some wood, old 5 gallon paint drums, and discarded (probably non-functioning) equipment.

Daily life in the hab itself produces a significant volume of items that would normally be recycled. Alas, Hanksville is quite small, and rather isolated; there is no place that accepts recycling within a hundred miles. So there really is no practical way to recycle paper, plastic bottles, or aluminum cans, unless one hauls them back to Denver or Salt Lake City. These items are not sorted, but just discarded with other household trash. Plastics #1 and #2, glass bottles, and aluminum cans are regularly available as well as the PVC and other items stored in the scrap area because they are too large or bulky to fit in trash bags.

With the right "spirit," all of this scrap and trash becomes "opportunity."

How so?

On the frontier, art and craft will play a major role in making us feel at home. But the sort of preferred art and craft materials with which those with artistic and crafts-man talent are used to working will be in short supply, exorbitantly expensive to import from Earth. But even on Earth, many an artist and craftsman cannot afford the preferred materials. When you have more talent than money, anything free that is workable will do. All you need is the appropriate tools for the chosen materials, and inspiration.

All of the materials mentioned above have been used by others to create art and artifacts. For inspiration, simply do a Google search; you will find websites with content to get your imagination started on aluminum can art, PVC art, plastic bag art, and more. You will find more help at your local library or arts and crafts store.

Now you might think that this kind of "crude" art is good mainly to teach children creative self-expression or to give bored old folks something to do. But it is really a matter of talent and creativity. People who have it have turned out some beautiful creations out of trash. There have been prestige exhibits that feature creations from recycled items exclusively.

Art & Craft at Mars Desert Research Station

What's any of this got to do with the Mars Desert Research Station? In the evening after the work of the day is done, we write our reports and the balance of the time before we turn in for the night is ours to use as we each please. We can watch movies, play games, get lost on the Internet, or -- work on some project. There is no reason why art and craft cannot or should not be engaged in.

Not every volunteer will feel the urge to express themselves in some physical medium. While there is great effort taken to balance the talents of crew members, and almost every crew will have some creative people, that doesn't mean that there will be a painter, sculptor or other kind of craftsperson.

But if you are the type, and are chosen for a crew, you should know that these possibilities exist. Of course, nothing in the rules or guidelines prohibits crew members from bringing along art and craft materials of their choice with which to pass free time hours.

Wisconsin Mars Society intends to assemble and ship a kit of tools and books for future crew members to use to try their hands at creating things from commonly available scrap and trash items at MDRS.

Art & craft produced at the Mars Desert Station can be brought home as souvenirs or sold at auction at a Mars Society Convention to help raise funds for the analog program. But it can also be used to decorate the common and private areas of the Hab itself. And that would indeed be simulating what will happen on the frontier. These options seem exciting to me, and I just thought I'd like to share that with you. <PK/WMS>

Our Own Lunar Analog Research Station?

What we might want to do differently

By Peter Kokh

Even before my recent two-week stint at the Mars Desert Research Station in Utah, I started keeping a file of ideas under the heading "what we might want to do differently at our own Lunar Analog Station." Grant you, that is not a near term project. But planning ahead is good.

Location: there are two schools of thought here:

- Put it in the heart of a high traffic tourist area such as Las Vegas or Orlando or even Chicago.
- Set it in a location where the terrain is suggestive of moonscapes: on a lava flow sheet, with access to lava tubes, perhaps

I do not believe you can satisfy both objectives without serious compromise. Further, tourist traffic and serious research without tourist interference do not go hand in hand. We do need both, however. The answer is to build two stations (two identical stations are cheaper than twice just one.) We have one in a high traffic area for tourists and public education, the other in an isolated location where we can do serious work. Web cams at the research station will feed monitors at the tourist facility.

Logistics: While isolation is great, logistics can be a continuing problem. The closest major airport to MDRS is 240 miles away in Salt Lake City. Travel is over good roads, but only a quarter of it is by Interstate. The nearest hardware store is 115 miles away. The nearest home center 165 miles. Can we do better? Not sure. One site I looked at , the Black Rock Desert lava flow area in Utah is 150 miles S of Salt Lake City, almost all of it on I-15, but the terrain proved unsuitable. Craters of the Moon National Park and surrounding Bureau of Land Management area in Idaho are just as far from Salt Lake as MDRS, and only a little closer to Boise, only a regional airport. Bend, Oregon doesn't fare that much better. We have plenty of time to search.

Habitat Design - Profile: I understand the origin of the Mars Hab shape, but it is a mistake. The Mars Society has backed itself into a corner on this one. The two floor Hab would be a bear to shield (if the Mars Society wanted to do so.) I recommend we look for some sort of Lunar Ranch design. Shielding is essential on the Moon, both for radiation protection and for thermal equilibrium. By looking the other way on this, the Mars Society people have got themselves stuck with an unnecessarily short field season: a shielded Hab could coolly function throughout the summer.

The Artemis Moonbase triple SpaceHab is one floor but way to small to serve as a functional outpost, even as a starter outpost. Two or three of them, linked? Perhaps. Let's not be bound to the venerable SpaceHab design. We could either start from scratch, or sticking with the Artemis module for a starter core, add additional modules of the same or new designs, perhaps even an inflatable (so long as the height to width-length ratio is kept low.)

Hab Design - Function Space: The Mars Hab's two floors with a combined floor area over a thousand square feet or 110 m2 is already much bigger (c.4x) than the Artemis Moonbase core module. But it does not serve all functions adequately. MDRS is in dire need of expansion. (See my report above pp. 37-41.) We need a separate tool and fabrication shop, and perhaps a dedicated hobby and "putzing space." An isometrics exercise room would be great.

Acoustics at MDRS are very poor, more so because it was given no attention in design and construction. Dust control is also a severe problem. Our facility needs to be much closer to airtight, relying on air-exchanges and plants to keep the air fresh, not loose joints and holes. Proper design of entrances (airlock-hatches) and their porches, steps, and aprons will help.

Hab Design - Utilities: It would be ideal to mimic the situation on the Moon as far as practical. We might advance towards heavy use of photovoltaics (solar power) to run all the lighting (12 volt) and at least all the lower load outlets. Where we need appliances and equipment for which 12 volt versions are not available (yet) we will have to do with 117v AC power. MDRS uses diesel-fueled generators. Is there is a more appropriate option for us? We should look for one. Fuel Cells? Again, solar power is the optimum, and that means picking a site with a high percentage of sunny days. No propane stoves!

Hab Design - Interiors: The first Moonbase will be manufactured on Earth. But we have time to incorporate into our research station features that mimic what pioneers can produce on the Moon. No wood 2x4s or Drywall (sheetrock) when for little more we could buy steel 2x4s and Duroc™ (fiberglass-faced cement board™) panels on interior walls, and something like glassboard on exterior surfaces. If we are going to set the mood for simulating outpost life on the Moon, we owe it to ourselves to do it right inside and out.

Life Support: We cannot expect to be able to provide total life support on any reasonable budget. But we should work aggressively to go beyond the gray water (sinks, showers) treatment demonstrated at MDRS towards at least partial black water (toilet wastes) treatment combined with food production. The Wolverton system is a place to start. This ambitious goal implies year-around occupation or tending.

Medical Systems: MDRS has an excellent first aid kit and daily email contact with a doctor. Can we do better? It is worth discussing. In reality, many medical emergencies will have to be treated on location. On the Moon, transport to Earth is only an option for postponable procedures.

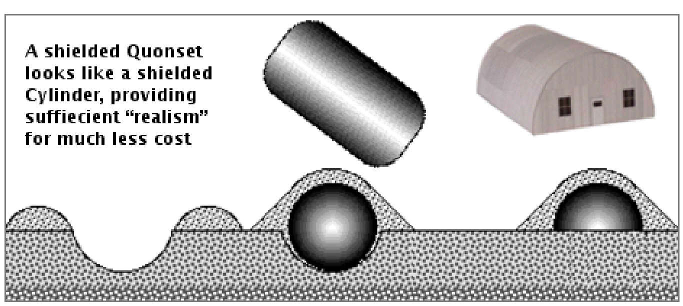
Crew Life Styles: We need prior commitment from our volunteers to participate wholeheartedly in experimental pioneer vegetarian food preparation and menu development. It's a matter of getting into the spirit and will generate good publicity. But we should also incorporate time, space, supplies and tools to allow experimentation with pioneer-appropriate arts and crafts.

Facility supported research: Geology and microbiology are big items at MDRS, and that is quite appropriate for Mars. On the Moon, there is no question of life: those into biology are better occupied developing our biospheric life support systems. And we have already done considerable geological investigation on the Moon. More remains to do. The point, however, is that unlike a Mars base, where exploration is goal one, on the Moon, developing ways to tap local resources and start making stuff is at the top of the list. From that point of view, the visible appearance of the host terrain is less important than its geochemical makeup. Basaltic areas that do not necessarily remind one of the Moon will still do fine. If we can have both, better!

We need to prioritize the things we want to demonstrate: shielding emplacement; regolith handling; oxygen production; cast basalt technologies; ceramics; glass composites perhaps. There is a lot of things we can do.

Talented volunteers or ....? The Mars Society has done a splendid job of attracting talented students with masters and PhD thesis projects worth demonstrating at MDRS, projects in the fields of geology, biology, and astronomy. While we can attempt to do the same, changing the stress, however (especially in biology), what we want to do in the area of demonstrations suggests that we prime the pump by organizing engineering competitions on the college level: competitions for automated or teleoperated shielding emplacement systems, for example, with the winning team getting to do the final demonstration at our location. Such an effort would build enthusiasm and provides plenty of publicity at every step. It also builds local cores of support.

Summing up: I have been a very strong, ardent and outspoken supporter of the Mars Society's analog station program from the day it was first announced. They have done wonders on a small budget with volunteer resources. Their program deserves respect. Even after two weeks spent at MDRS in Utah, and seeing all the room for improvement, I am still a strong supporter. It will not be easy for the Moon Society to improve on what they have done. However, we have the benefit of time on our hands. We can afford a more deliberate, patiently methodical approach. Our needs differ in part. We can do it, given time, but only if we don't wait until we have the money to start brainstorming and planning. Let's start now. <PK>



Horizontal "ranch style" structures are easier to shield.
Structural fidelity is not needed for many research areas

How and Why we should participate in the Mars Society's Analog Station Program, both for our own purposes and for purposes we hold in common

By Peter Kokh. Interim Project Manager

This is a topic I wouldn't be writing about had not Mars Society President Robert Zubrin announced at last years Convention in Chicago, that he was willing to discuss MDRS rentals for two-week periods by other groups with compatible goals. MDRS is not ideal for Lunar Outpost Simulation Exercises, but it beats the heck out of what comes in second -- there is nowhere else comparable.

The Costs

Let's put on our gray-tone glasses and take advantage of a windfall opportunity. MDRS cost the Mars Society well over a hundred thousand dollars, just to build the Hab shell. Erecting it, outfitting the interior, installing all the utilities, preparing the site - that cost much more. It's ours to rent for the nominal sum of $7,000 for a two-week period. Add to that a food budget, transport costs from whatever staging points we use (Salt Lake City, UT or Grand Junction, CO by air, or Green River, UT by bus or train), and the purchase, rental, or development costs of any special equipment we want to bring. Crew volunteers pay their way to SLC or Green River.

What we can do there

In our "Initial Project Feasibility Findings: A "Go" for MDRS Moon Mission #1" November 20, 2004, we out-lined quite a number of useful exercises in which we might engage with the expectation of learning something. After two weeks spent on location this February, with a few additions and subtractions, that prognosis remains valid.

It makes sense to collaborate with the Mars Society in this way because many aspects of frontier life will be the same on both worlds; because, also, Mars and the Moon are natural trading partners, each enhancing the viability of the other. It also makes sense because it will better prepare us to locate, design, and outfit our own Lunar Analog Research Station so that it bests serves our needs, when that day comes. It makes sense too, because such a rental will give us badly needed media exposure, more respect among our peer associations, and make us more attractive to prospective members. It makes sense, from many points of view, because it will use our talents and energies efficiently to do what we can as a society to advance the day when humans will live and work on the Moon into the indefinite future..

Our Moon Mission Crew will go the extra mile in simulating lunar life inside the hab as well as outside. We may make lasting contributions to the MDRS operation. We will join the growing fraternity of MDRS alumni. Turf-retentiveness has gotten none of us anywhere. The time for collaboration is now. It's in our own best interest. <PK>

Utah's Black Rock Desert

A Lunar Analog Site? We Paid a Visit

Report by Peter Kokh

In preparing for my February trip to the Mars Desert Research Station, I spent some time familiarizing myself with Utah. In the process of doing so, it occurred to me that there might be distinct networking advantages if we could find a suitable Lunar Analog Landscape somewhere in Utah. It took only a few minutes via a Google Search for "Utah Basalt" to lean about the Black Rock Desert area, roughly 140 road miles to the west of Hanksville where MDRS is situated. The BDR includes several discrete areas of lava flows younger than a million years old, in some cases, only a few hundred years old. The areas are clearly noted on my Utah Road Atlas as jumbled or chaotic terrain. The nearest portion lay a few miles west of Fillmore, 150 miles south of Salt Lake City on I-15. I programed myself to pounce on any opportunity to have a look see.

The opportunity I hoped for came and went, or rather disappeared. Then by luck, a replacement crew member let us know that she was renting a car to come down from Salt Lake City two days early, and would I be so kind as to return her rental car? I was only too happy to be so kind, and when it was my time to leave, I took the long way to Salt Lake, making just enough time to take in Fillmore.

As you drive west on a fine-grain gravel road, that I soon realized was paved with crushed lava pumice, all of a sudden you see a black wall in the distance. It is the edge of the lava flow, perhaps 10-20 feet higher than the neighboring terrain. But as I got closer, I could see that the lava flow was liberally dotted with very green foliage of some sort of bush-like plant. Continuing on, I noticed how lumpy the surface was, as if consisting of lava boulders of all sizes placed cheek by jowl. While you could cross it in a tank crushing a new roadway in the process, it looked to me to be extremely difficult for traverses on foot. You couldn't walk more than a few yards without twisting an ankle!

Another oddity. About a third of the clumps were distinctly rust colored, the rest decidedly black. How did that come about? I remain perplexed. I took samples.

The upshot was that with all that vegetation and with the pedestrian unfriendly surface, the site did not seem worth a second look. Are all areas of the Black Rock Desert basalt flows like this? I didn't have time to ask any locals before I had to hustle to make my afternoon flight back home.

This first (new) attempt to look for a site was a strikeout. (In 1992, I had the opportunity to tour the pair of lavatubes outside Bend, Oregon then used for the Oregon Moonbase. That site seems in retrospect much more appropriate. However, it is no longer available.

We have ample time to continue looking. PK

MMM #193 - MARCH 2006

From the Arctic & Desert Analog Stations to a Real 1st Human Outpost on Mars
Changing Mission Plans to fit the many lessons learned on Devon Island and in Utah

By Peter Kokh, MDRS Veteran, Crews 34 & 45

The Mars Direct Mission Plan Revolution

Mars Direct, the Mars Mission Architectural revolution introduced by Dr. Robert Zubrin more some fifteen years ago, showed how we could mount exploratory missions to Mars with far less throw weight, total tonnage to be paid for dearly with fuel, than NASA's then conventional mission architecture forecast as necessary. By the simple device of making the fuel for the return on Mars itself, instead of carrying it along, as well as all the fuel needed to get that return fuel to Mars, the cost of human missions to Mars was cut to a tenth. Now exploring Mars became something we could budget for, something in 1960's dollars, not much more than another Apollo Program.

But another Apollo Program, a heroic Flags & Footprints Epic to be followed by yet another half century of nothing, is not exactly what we need. By the plan, if the first unmanned crew return ship lands successfully and produces fuel successfully, then, at the next launch window 25 plus months later, a manned Habitat would be landed at the same site, along with a second unmanned crew return ship with fuel making capacity to a site reachable by the first party if necessary. Then another manned Hab would be sent to that second site, etc. Over a period of 8 years, three manned Habitats would be established on Mars, each to be abandoned when its crew went home.

First things first! Settling in before Exploration!

While this plan introduces measures to guarantee a safe return of each crew, and to gradually extend the reach of manned exploration across the globe, it clearly puts exploration ahead of establishment of even one viable outpost. In fact, none of the three manned Habitats would be viable for more than weeks, in our opinion. They are each too small to house all that is needed to sustain a crew for up to two years in good physical and mental health. I say that having spent two 2-week tours of duty at the Mars Desert Research Station in Utah.

Before I make that particular case, let me advocate clearly and forcefully that exploration should follow, not precede establishment of a permanent outpost. We know far more about North and South America and Australia through exploration by their own settlers, than we could ever have learned from a series of expeditions leaving from and returning to Europe. Why? Logistics, logistics, logistics.!

Exploration is best done from up close, by people living off the land, because it is their land. We must not let the curiosity itches of planetary scientists be scratched at the expense of settlement. In the long run, settlers will find out vastly more about Mars than "foreign" explorers bent on leaving the land they are exploring.

The Mars Analog Habitats tell the tale.

The Mars Hab testbeds at the Flashline Mars Arctic Research Station on Devon Island and at the Mars Desert research Station in south central Utah, are classical cases of design according to the principal "function follows form." Yes, I know that's backwards. That's precisely the point. Instead of defining the facilities and functions we need in a self-sufficient crew habitat, and then finding a modular architecture to house those functions, we have settled on a fixed volume structure, determined not by the needs of usage but by the needs of transportation to the site. Then we have sought to cram all the needed facilities and functions into that fixed volume.

And guess what? They don't fit.

That's not apparent to many crew members because they are there for a 2 or 4 week tour of duty. But Mars crews, on the real (not analog) Mars will make that Hab home for two years or more. If FMARS and MDRS veterans are honest, they will realize that neither Hab can produce its own food, produce its own energy, or keep itself in good repair without all too frequent outside inputs, help, rescue, and resupply – recourses that could not apply on Mars itself.

There is no real allowance for crew recreation – on two week tours, you can simply go without. There is no real attempt to rely solely on original rations and food grown on site in a greenhouse. There is no capability at either location for making parts needed for repair. Again, the Classic Double Tuna-can Hab does not have the space to provide these functions, yet we would send crews in such a cages to Mars. And rather than add additional structures to this complex of one, we would send new Habs elsewhere on Mars.

An Alternative Plan

I think we should send to Mars three or more Habs, each differently configured, to the same site, along with other ancillary structures, including inflatable ones.

If we do not establish a viable outpost on the first shot, we may never, ever get another chance.

Exploration will take care of itself. Other things come first.

For starters, we need:

- A food-growing greenhouse large enough to feed a double crew, should the firsts crew not be able to return home when their relief arrives. A diversity of crops, and several species each would be needed to protect from collapse from blight or disease. A greenhouse operation can never be too big. Witness Biosphere II.
- A greenhouse-based life-support system with air and water recycling with some chemical/ biochemical assist, as needed, to be slowly phased out on Mars.
- A complete machine shop and fabrication facility. Mars is not the Moon. It can have no umbilical cord to Earth for repair, resupply, or rescue. A Mars outpost must make do on a Yolk

Sac of parts and supplies sufficient to last for several years and with the capacity to self-manufacture unforeseen needs.

- A complete pocket-hospital. It is one thing to take a chance with crews on the Moon where return to Earth is relatively simple. The longer the stay, the more certain real medical emergencies, both trauma accidents and other emergencies will arise. A first aid locker won't do.
- An exercise facility, diversified recreation facilities, support for hobbies, arts & crafts
- A lab where experiments can be made with locally produced building materials aimed at self-manufacturing as many of the physical needs of the outpost as possible, including expansion of the outpost.
- Establishment of a Remote Way Station, a few miles away, where EVA exploration crews could overnight, and to which crew members could retreat for brief periods of quiet rest and privacy in relief of tensions.

Teleoperations Vantage Points on Phobos/Deimos

Nothing leads to failure more surely than impatience. Impatience to explore is an example. Once we have a growing crew at a growing outpost, we will have personnel who can be tasked with the teleoperated exploration of Mars by a whole fleet of mini-rovers and drone aircraft, operated in near-realtime via relays on Deimos and Phobos where the transmission delay is only a fraction of that for the Earth-Moon loop. Manned expeditions could then be sent to the most interesting spots, rather than waste their time on less interesting areas.

Crew expansion leads to economic diversification

Once an outpost, the outpost, is clearly viable and at least partially self-sustaining, crew members could be given the opportunity to renew or re-up their commitment. Compatible couples could choose to do so, forming the first families on Mars. We have to shut our ears to those who say we can't allow births until we know for sure that humans can survive long term on Mars. Why? Because the only way to know that is to see how the second native born generation turns out, and that means taking the plunge without delay. The is no believable ivory tower way to find that out. If humans had always been so "timid," (let's call a spade a spade) we would still be in the rain forests or plains of Africa or in the caves of Europe. It is human to take the plunge, as an exercise of faith in the capacity of the human genetic architecture.

One outpost, repeatedly revisited by supply ships, can grow methodically. As it grows, a more diverse slate of occupations can be supported. Made on Mars consumer goods will be first produced by workers with day jobs in their free time, as cottage industry startups. More and more personnel will be freed from outpost support duties to partake on further exploratory expeditions. Once the needs of outpost expansion can be met with home grown industries, we will have the start of a new civilization on Mars, one making real steps towards an independently viable future. And that, after all, is our Holy Grail.

Bidirectional lessons: MDRS to Mars and Mars to MDRS

Consequences flow forward and backward. We can see from what has happened at FMARS and MDRS that the Hab plan will not work for Mars as the plan now stands. The flip side of the coin is that it is not working even now in the Arctic or in Utah. Yes, we simulate exploration procedures, geology and prospecting procedures, exobiology procedures. But we don't simulate the isolation without hope of relief for two plus years.

It would be both valid and honest to say that the Mars Society has had to choose its battles. Some battles are more easily won. The engagement in others seems beyond our grasp as a small nonprofit society. But we ought to advance steadily in that direction, especially since those battles must be won before we dare set out for Mars.

Picking a site on Mars - a prime candidate

If we are to settle on just one landing site, we need to pick that site with care. As of now, we have but a foggy start to an Economic Geography of Mars, tracing where all the resources are, the logistical advantages, the logical transportation corridors, a priority list for 2nd, 3rd, and following outposts needed for a trading economy on Mars itself. We can expect this hazy map to become a bit clearer by the time the first crew leaves for Mars.

In the meantime, this suggestion. Pavonis Mons is one of Mars four largest shield volcanoes. Almost as tall, but not quite as large in area as Olympus Mons, it more than makes up for any shortfall by its location, smack on the equator. Its summit caldera rim would be the best spot in the inner solar system to anchor a space elevator (we have to figure out how to avoid Phobos which crosses that path) and its gentle west slope, the ideal place in the inner system for a mountain launch track. The eventual establishment of either would greatly lessen the cost of exports to the Earth-Moon system. More, as a shield volcano much like Mauna Loa/ Mauna Kea on the island of Hawaii, it is almost certainly laced with intact lavatubes. In "The Argument from Medicine Lake" (MMM # 74 March 1994, p. 3, republished in MMM Classics #8, pp 12-13) Bryce Walden conservatively estimates that Pavonis offers 333 km2 = 128 mi2 of usable sheltered floor space, the size of a major American central city in the one million population range.

But the outpost doesn't have to be on/in Pavonis Mons itself. It could be to the West, between the outer mountain ramparts and the crater Ulysses - call it "Ulysses Junction."

Or it could be east, between Pavonis Mons and the Head of Valles Marineris. While undoubtedly, other sites will have some merit, a location along the equator to either side of Pavonis Mons will certainly be in the running and hard to out-merit. Again, exploration goals and geological and scientific curiosities should score no points. They are irrelevant to the overarching need to establish an outpost beachhead of humanity on Mars "securely."

De-marginalizing the Mars Analog Stations

Back to the Mars Society's analog research stations - FMARS is already pre-marginalized by the extreme climate on Devon Island as well as the order of magnitude greater cost of logistics: transportation and supplies.

MDRS has been marginalized unnecessarily, we believe, in the absence of a decision to shield it. Shielding, which will clearly be needed on Mars to attract those unwilling to sign waivers that accept the chances of cancer and risk of reproductive sterilization, is one of those things we have silently put on the list of things not to simulate.

The tall profile of the Hab (again, putting form before function instead of vice versa) makes shielding difficult. A Horizontal ranch-style complex would be much easier to shield. While the landlord, the U.S. Bureau of Land Management, BLM, would not take kindly to wholesale earth-moving, shielding could be simulated in easily removable fashion by bags of mulch, for example.

The thermal equilibrium to be gained would result in a significantly longer field season, now limited by summer heat, and thus make possible a true greenhouse, not the very limited graywater recycling GreenHab system we have. Yes, there are other summer heat related issues: cooling the EVA suits for example. But these too are surmountable.

The existing facility could grow, adding a horizontal crew quarters module, reoutfitting the present Hab structure for a more complete lab (whole second floor deck now given to crew berths, ward room, galley, computer stations) and a much expanded engineering, machine shop, fabrication space on the first floor deck. But where we put what is another question. The priority is to expand, create more usable space.

What about FMARS?

The "first-born" has a special place in the affections of Mars Society members. Devon Island offers a different kind of Mars Analog Terrain. The fact remains that any facility not used full-time is too expensive per man-hour of use to maintain.

It would be a hard choice to take it down, ship it to some other location where it could enjoy full(er)-time use and reassemble and reoutfit it. There are cost-benefit issues that come into play but which can only be correctly assessed if we take the long view. Have we done about all we can do on Devon Island? If so, the time has come to take a fresh new look at this asset and how it can best serve the dreams of the Society.

Relocation of the Arctic Hab to a new home side by side to the Desert Hab and then rethinking how each is outfitted, is one option it will do no harm to brainstorm. The result? A more complete outpost capable of simulating more of the facilities and activities a real outpost must have.

Another idea would be to relocate FMARS to the Orlando or Las Vegas areas as a tourist center. Both MDRS and Euro-Mars have indeed been on display, but in each case, that was prior to interior outfitting. The upshot is that the visitor did not get a good idea of what it would be like to live and work in such an outpost. Missed Opportunity!

In an FMARS tourist facility, visitors could see how and where crews live and work, both by walking through a nearly identical layout and through live web-cams to all of the activity areas of MDRS. Such a facility could pay for itself and the whole analog station program by visitor donations.

Then with FMARS retired to visitor duty, MDRS could be logically expanded first by inflatables, outfitted with local materials, then by modules produced and outfitted from (simulated) local (Martian) materials. This would provide a much better model of the way we will need to do things on Mars if we don't want the Mars Program to end as the Apollo one did, as a futile "moment of glory" dead end. We are here to make "History," not an "Historical Moment!"

Summary

The present goal of the Mars Analog Research Station Program is to establish a series of minimal stations at a multiplicity of sites that are each analogs of Mars in different ways. Many things cannot now be modeled or simulated because of the Procrustean limitations of the form/shape/size of the Hab design based on transportation constraints. It would seem better to go beyond the simulation of exploration procedures and the testing of equipment. We need to phase in simulation of transition from initial bare bones outpost into a viable permanent beachhead.

Establishment of a more capacious foothold with endurance capacity is much more important than butterfly sampling of many locations. Exploration, and much, much more of it, will be best guaranteed by establishment of a viable beachhead as the primary goal of a Manned Mars Mission program.

Currently, the separate Mars Foundation works on its own to find pathways to settlement. The Mars Society needs to collaborate with the Foundation to vastly improve its analog program., which is currently aimed only at the exploration of Mars, not settlement.

If we want to simulate what we will need to have on Mars, we must grow MDRS as we would the first outpost on Mars.

It's all so simple, really. <PK/MMM>

[We realize that this article will prove to be quite controversial, "apple cart upsetting." But it often happens in any movement that a time comes when we must stand back and ask, "are we still on the track? Or did we get off it some-how? If so, how do we get back on course to our dreams?"]

MMM #195 - MAY 2006

What a Lunar Analog Research Station Should Attempt to Demonstrate

By Peter Kokh and Moon Society Advisor David A. Dunlop

First let's clear the ground by pointing out that the goals of a Mars Analog Research Station are not necessarily the same as those of a Lunar counterpart, and vice versa.

For Mars advocates, the goal to be defended, the feasibility to be demonstrated, is that humans and robots together can explore Mars much more effectively and thoroughly than robots alone.

Mars advocates are trying to get the nation (and, hopefully, international partners) to commit to the manned exploration of Mars. Settlement, while a dream of most, is a goal well over the horizon.

In contrast, Lunar Advocates are operating with a given national commitment to a "permanent" manned outpost on the Moon, whatever "permanent" means.

We have many times pointed out that any outpost remains tentative until there is a permanent civilian population on the Moon raising its own successors, and supporting its own domestic needs as well as earning credits towards imports by products and services based on local, i.e. lunar resources.

We have already had humans on the Moon exploring limited areas. Manned exploration is not something whose feasibility we still need to demonstrate. Thus **our goals go beyond those of Mars advocates.**

- We do not need to demonstrate the methods and tools of human-robotic exploration,
- We do need to determine which operations can be done effectively by teleoperation from Earth in order to dedicate precious manhours on location for those things that can not be done as well by teleoperation
- We do need to demonstrate the methods and tools of expansion of an outpost into a settlement.
- We do need to demonstrate the options for using local lunar resources to accomplish that goal.

Demonstrating Maximum Use of Teleoperations

Our long term goal is to ensure the creation of a viable lunar frontier where people of many walks of life can work, play, and raise families, supporting themselves by the production of export goods and services. To the point, there is one thing in common with all "new frontiers" in the early stages of establishment.

There is always more work to be done, than people to do it.

Our best opportunity to make sure that precious man-hours are most economically spent is to identify and demonstrate operations that can be effectively performed by personnel on Earth, "teleoperating" at far lower costs per hour. The Moon has the advantage of being only one and a fraction light-seconds from Earth, a manageable time delay.

Site preparation (grading, leveling, removal of boulders, trenching, etc.) and shielding emplacement are two obvious areas where teleoperators working on Earth should be able to get the job done, leaving crews on the Moon for other things, not so easily "farmed out." But we need to determine the best equipment to be sent to the Moon for teleoperators to control with under 3 seconds time delay.

What other operations can be so farmed out? Here lies a whole world of things that can be tested at a lunar analog station. Every operation that can be done remotely, extends the productivity of those on location that much more. Advance scout rovers could be teleoperated; mining equipment, manufacturing equipment, agricultural tasks, perhaps even road construction. Let's find out!

Demonstrating Dayspan/Nightspan Power Generation

An outpost needs power, of course, but NASA is not currently committed to demonstrating a system to store power for use during nightspan. Instead, the agency seems committed to demonstrating that the need to do so is unnecessary, because the outpost will be at the South Pole, where allegedly sunlight is available all the time.

If we are going to bring the whole lunar globe into the realm of a Greater Earth-Moon Economy, we have to be able to set up shop wherever resources and other assets demand that we do so, not just at one of the poles. And that means demonstrating a Dayspan/Nightspan power system. Indeed, we should demonstrate several systems, not only for backup, but so that the technology can pick the winners.

The options are several. A small nuclear power plant is, however, something totally out of reach financially for a privately supported Lunar Analog Station here on Earth. But that doesn't really matter, because outposts and settlements will come in all sizes, while "nukes" may come only in one size, at high expense, a non versatile solution.

Hydrogen/Oxygen Systems: Fuel Cells

Excess dayspan solar power could be used to electrolyze graywater and water in reserves into hydrogen and oxygen which can be recombined in a fuel cell to produce both power and potable water. Fuel cells could also be fed by hydrogen scavenged from solar wind volatiles by heating regolith soil being moved in the process of road construction, materials processing, site grading and excavation, and import of regolith into pressurized farm areas for use as soil. Fresh oxygen can be extracted from the regolith by several well-understood and demonstrated processes. Harvesting hydrogen and extracting oxygen would be day-span activities.

Hydrogen/Silicon Systems:
Silane-fueled Generators, Vehicles, and Appliances

Another entirely different possibility should be explored. Carbon is scarce on the Moon, much more so than hydrogen. Thus methane is not a fuel option. But Silane, $SiH4$, a silicon analog of carbon-based methane, may be.

Silane could be called a "hydrogen extender," in as much as silicon, being much more common on the Moon than hydrogen, is used to stretch the total power output of a given amount of hydrogen. Silane has been proposed as a lunar appropriate rocket fuel.

I had some time ago asked Dr. Robert Zubrin if the adiabatic process (occurring without loss or gain of heat) to be used in making methane from the Martian atmosphere could be applied to production of silane on the Moon. He answered in the affirmative. That leaves us with the belief that this is a direction worth pursuing.

- First we could demonstrate methods of producing Silane from regolith. Engineering competitions at the College- University level are an option worth pursuing.
- Then, by similar competitions, we could seek to demonstrate silane-fueled generators, silane-fueled vehicles, and silane-fueled appliances.

The Silane would be produced during dayspan in quantities sufficient to fuel appliances and vehicles at all times, and generators during nightspan. Silane-fueled generators could also be used at all times at small construction camps and other temporary installations where it makes no sense to deploy a large scale solar (or nuke) power system.

Continuing productivity through nightspan by "change of pace" task sequencing

Few things need demonstration as much as the ability of pioneers to survive the two week long lunar night. Here on Earth, alternating fortnights of full daylight and total darkness (except for Earthlight and starlight) within a warehouse or arena with blacked out windows and total lighting control. But we can come close at an outdoor Habitation structure such as the Mars desert Research Station, by having the crew active for two weeks during local daylight hours, then shift to a schedule offset by 12 hours, awake and active only during the local Utah night. The portholes and windows could be blacked out, or uncovered, as needed to create the right atmosphere inside. Crews would go outside only during daylight, and nighttime hours alternately over a four week cycle.

We might learn more from week 1 dayspan, weeks 2 and 3 nightspan, week 4 dayspan. That way two transitions, from abundant power to rationed power, and from rationed power back to abundant power could be modeled. If we could only afford to rent the MDRS facility for two weeks, we could operate on a 4 day light, 7 day dark, 3 day light schedule, telescoping the lunar cycle into half the time.

In such a light/darkness regime, crew members could experiment with the management of operation tasks to suit the greater amount of power available during the two "daylight" weeks, and the lesser amount available during the two "nighttime" weeks. Various tasks could be separated or precipitated out into energy-intensive ones to be executed during the light period and energy-light and perhaps labor-intensive tasks to be taken care of during the night period. Some operations will lend themselves to such a sequential execution; others may not. It will be a learning experience.

Meanwhile, we can demonstrate power generation during the dayspan period by use of photovoltaics, and solar concentrators, and other means. During this period, excess available energy would be used to electrolyze graywater, as suggested above. For backup to fuel cells, we could develop and improve silane-fueled generators, furnaces, ranges, refrigerators, and rovers.

For more on the topic of dayspan-nightspan task sequencing, confer these back articles:

MMM #7 July, 1987 "Powerco" - reprinted in MMM Classics #1, pp. 21-22
MMM #43,March,1991 "Dayspan," "Nightspan" - reprinted in MMM Classics #5, pp. 10-12
MMM Classics Pdf files are freely downloadable at:www.moonsociety.org/publications/mmm_classics/

Modeling "Modular Biospherics"

1. Modules for expansion

Expansion of our outpost(s) is(are) can not reasonably be supported by the prohibitively expensive import of habitat modules and connectors manufactured on Earth. With so astronomically expensive a cost pre square foot of usable space, the governing constraint will be to jam pack each unit with equipment, reducing crew quarters and recreation space to "sardine can" cubbyholes, and making many desirable activities much too expensive to support.

The next step would be to bring in inflatable structures packed uninflated and compacted for the ride to the Moon in constraining payload bays and farings, then finish outfitting them on location. These could be spheres, cylinders, or torus-shaped volumes. The latter provides a stable "no-roll" level footprint and the greatest volume to height ratio, making shielding easier. While inflatables designed for use in low Earth orbit must have foot-thick membranes to protect against puncture from orbital debris, inflatables designed to be covered with shielding on the Moon would need only a much thinner membrane, meaning that inflated, they could provide significantly more volume (with perhaps ten times the membrane surface area) than similar LEO-destined inflatables, when both are to be transported in the same size payload bay or faring. The real challenge of inflatables is to design interior systems that can be quickly and easily deployed, once the structure is inflated. Again, college level design competitions may prove useful in coming up with elegant solutions.

The real breakthrough, however, will be the achievement of the capacity to manufacture modules and module components locally on the Moon with made-on-Luna building materials: metal alloys, glass fiber reinforced concrete, glass-glass composites. The price of new space will be reduced drastically. The outpost will grow module by module, along with the crew - the population.

2. Making each module of the growing structure, also a module of the growing biosphere

Meanwhile, we will have to grow the biosphere that supports the complex. The simplest and most elegant way to do this is to equip every lived-in, worked-in, played-in, learned-in module with a Wolverton* type toilet system that flushes sideways through the bathroom wall to water a row of platers beginning with water plants, swamp plants, marsh plants, bog plants and then soil plants. By the time the black water leaves the module, it is 95% pretreated, vastly reducing the load on a central water recycling system.

* To learn more about the Wolverton System, check out: http://www.wolvertonenvironmental.com/

These "principles of modular biospherics" are something worth modeling and demonstrating at a Lunar Analog Research Station. Such a system will go well beyond whatever system NASA uses to refresh air and water in a fixed size outpost, and thus demonstrate the technologies needed for expansion of an outpost into a real settlement.

The modules would need to pipe in sunlight or alternately, banks of grow lamps. (The pathways provided for sunlight could be used by light from intensely bright external sulfur lamps during nightspan.) The plants within each module would largely refresh air within, and fill the interior with the greens of vegetation and the color of flowers: fresh air, greenery, color – not an add-on but an integrally designed feature of each module.

In such a system, the biosphere grows one module at a time. The settlement's physical plant does not outgrow the biosphere's capacity because the two are one and the same. Not just the major modules that comprise living, working, and recreation space, but also the connecting passageways and "streets" should do their share by hosting plant rows along their sides. We must always keep in mind that it is not a case of humans playing host to house plants, but of vegetation playing host to humans, enabling our survival!

We could build our Analog Station with a mix of hard hull modules, inflatable modules, and modules made of materials we should be able to process on the Moon. Perhaps the core operations would be in the hard hull starter units:

- Crew Quarters – Library – "Quiet Spaces Module"
- Computer workstations: communications, controls, monitors, reports, teleoperations, CapCom, Office
- Kitchen, Pantry, Ward room, meeting space
- Bathroom, showers, exercise & fitness area, First Aid
- Lab space for work on geological and mineral samples
- Utilities: power, thermal control, engineering workbench
- Airlock and suit-up area. Dust decontamination

The above modules could be directly interconnected or connected via passageways, as the needs for isolation or of juxtaposition dictates.

This basic 7 unit complex contrasts with the all-in-one approach illustrated by FMARS and MDRS. The Lunar Analog Station, by beginning as a modular complex, would be set to grow in like fashion. Additional modules could be added for recreation and sports, arts & crafts space, and areas for experiments with processing and materials. The complex would begin to look like a self-sufficient commune.

All units would house vegetation. This would be in addition to the Greenhouse, itself modular, which could grow as success, food demand, and the desire for more variety increases. A Greenhouse area could host a picnic corner, a get away reading spot, a biocrafts area, and so on.

Thus a Lunar Analog Station would not be a weak "me too" operation, but one with rather ambitious goals that go well beyond what the Mars Society is attempting to do. It is only fair to point out, however, that The Mars Foundation is moving in that direction also. This group is attempting to identify all the technologies needed to transition an outpost into a permanent settlement on Mars, and dreams of building a prototype Mars settlement somewhere on Earth.

Other things worth demonstrating at a Lunar Analog Research Station

- Teleoperable shielding emplacement systems
- Erection of shielded hangers within which to indirectly shield pressurized modules and/or to house supplies and systems that need to be accessed on a regular basis
- Greenhouse systems
- Early industries: cast basalt, glass, fiberglass, glass composite, concrete, metal alloys
- Art media using only lunar producible materials
- Refurnish the Habitat with objects made in the above demonstrations. And on and on. Evolution of the Analog Complex with regular "Updating Makeovers" as new technologies are demonstrated

Of necessity, the initial complex modules will be built with available terrestrial materials. However, right from the outset, floors could be finished with cast basalt tiles made in Czechoslovakia and marketed in the US out of West Virginia. We could also start out with interior walls constructed not of 2"x4" wood studs and drywall (as is the case at MDRS and

FMARS), but of steel studs and duroc cement board. Not only would that be closer to what we might end up doing on the Moon, it would be a fireproof solution.

As we demonstrate new materials technologies, we could then replace more and more of the original materials, furniture and furnishings used in the station with those analogous to what we might be able to produce on the Moon. In this manner, the quality of the "simulation" would keep increasing – proof that we are learning things worthwhile!

A Lunar Analog Station as a Part of a larger Project

A Lunar Analog Research Station is but one part of a grander dream of the Moon Society, called Project LETO {Lunar Exploration and Tourist Organization], which would involve a major tourist and educational center. It is my opinion that the research facility should not be included in such a complex but located separately in an appropriate isolated landscape. However, a twin facility at the tourist center, evolving (expanding and upgrading) in step, would be available for regular tours. It would have monitors at each location to show web cam views of what is currently going on in the real research station.

The Mars Society relies on publicity for its analog stations to increase public support and funding. But a sister complex open to tours with a peep hole into the actual one, if located in a high tourist traffic area such as Las Vegas or Orlando, would greatly increase public exposure, public enthusiasm, and, equally if not as important, a steady flow of donations and new members.

What's Next for TMS-NSS collaboration?
Another Crew at MDRS? Moving somewhere else?

We can do some of these things suggested above at the Mars Desert Research Station in the 2007 Field Season – for example, a first modeling of operations through a complete lunar dayspan/nightspan cycle.

However, the demonstration of a modular bio-spherics expansion architecture, as it involves the facilities themselves, would necessitate an independent operation on a separate site. It would be foolish to make major capital investments in a facility not our own, and from which we planned to move. Further, there is no reason to believe that the Mars Society would approve any such expansion plans. If we want to do these things, we must find another site and deploy a fresh habitat complex of a friendlier design.

As for a new site for our new modular complex, locating it in a "lava sheet, lava tube area" would be optimum for silane and/or fuel cell based utilities, cast basalt operations and other materials processing and manufacturing operations we want to demonstrate. It will take some time both to identify a new site and acquire access and use.

It would take more time, and money, to deploy our desired complex. However, we could start with a mockup complex of rented or purchased used old camping trailers, replacing them one at a time with new construction. This is a plan that would involve the minimum interruption in annual simulation exercises, a plan that would maintain momentum. <**MMM**>

MMM #198- SEPTEMBER 2006

The Outpost Trap

Technologies Needed to Break Free

By Peter Kokh – selected portions

II. An Expansion-friendly Modular Outpost Architectural Language, and Construction/Assembly Systems Design

Back Reading:

MMM #5 May '87 "Lunar Architecture", MMMC #1

MMM #75 May '94 "Lunar-Appropriate Modular Architecture" MMMC #8

MMM #101, Dec. 96 "Expanding the Outpost", MMMC #11

This is one area in which the **Russian**s and **NASA** with its various **contractors**, have already done consider-able research and have acquired invaluable inflight/in-use experience in the **Mir** and **International Space Station** programs. Happily too, a commercial contractor, **Bigelow Aerospace** is now making groundbreaking contributions with inflatable module technology, borrowing heavily on NASA's Congress-aborted TransHab project. The prototype one quarter scale inflatable **Genesis I** is now in orbit and rewardingly performing well.

Modular architecture developed for the micro-gravity of Earth orbit will certainly have applications in the return to the Moon effort. It will apply directly to any way station developed at the L1 Gateway point or in lunar orbit. But applications to the design of lunar surface outposts will need some rethinking for four reasons:

We are now talking about a 2-dimensional environment stratified by gravity, not the any-which-way dimensions of orbital space. The 1/6 Earth normal gravity environment mandates an established up-down orienta-tion, no "swimming" through the air to get from one point to the other. This is minor.

Egress and ingress portals need to be designed to minimize intrusion of insidious moondust. It would be ideal if spacesuits were rethought with this challenge in mind, but NASA has already signaled its intention not to explore that route for money reasons. One more sorry instance of a "stitch in time, saves nine." NASA operations on the Moon will be far more expensive to maintain than the relatively trivial expense of wholesale spacesuit redesign even at multimillion dollar expense. Commercial contractors may be the Knights in Shining Armor here as the NASA approach would be indefensible in any business plan.

Outside the safety of the Van Allen belts, radiation protection is required for more than short stays. The lunar surface station must be designed to sit under a shielded canopy, or to be directly covered with a regolith blanket. An added benefit will be thermal equilibrium.

While NASA, its contractors, and the Russians have a head start, it should never be assumed that they have explored all the options. Modular architecture is very much structured like a language: it has nouns (the various habitat and activity modules), conjunctions and prepositions (the various connector nodes), and verbs (the power system, the Canadarm and other associated assembly and arrangement tools). The idea in constructing a "lunar-appropriate modular architectural language" is to come up with the most versatile, yet economic in number, set of modular components to support the most diverse and varied layouts and plans. The idea here is to maximize the options for expansion, without prejudging what needs will be accommodated first in the buildout.

We think that this concept is important enough to put to a design competition. NASA, contractors, the Russians can all advise on interface constraints and other design features that must be incorporated. Then let the would be Frank Lloyd Wrights of the lunar frontier have at it. We predict some novel suggestions that NASA and commercial contractors may want to adopt.

In Part I of this article, [not reprinted here] we suggested that modules should fit (yet-to-be-standardized Earth-Moon shipping pods. The cheapest way of providing maximum elbow room, in the era before modules can be manufactured on the Moon out of lunar building materials, will be inflatable modules. Easy to deploy "outfitting systems" for these inflatable units are another area worth exploring through the device of an international design competition. The inflatable manufacturer can set the constraints that will include interior dimensions, purchase points, and ingress opening sizes. Then let the contestants exercise their own inspirations.

Onsite manufacturability of needed components would be a design goal: maximum use of low-performance cast basalt, glass composite, and crude alloy items should be the preferred contest category. This way, expansion develops hand in hand with early startup industries, and becomes a strong incentive for their earliest development, saving substantial sums over importation from Earth.

Expanding on this theme, even equipment in hard-hull modules arriving fully outfitted from Earth might be limited to subassemblies of components not yet manufacturable on the Moon. A very simple example would be cabinets, tables, floor tiles, even chairs without horizontal tops or seats. These could be made of cast basalt, saving some weight in shipment. Many more possibilities of this compound sourcing paradigm are worth exploring: wall surfacing systems, simple utensils, appliance chasses, etc. See MMM #18, Sep. '88, "Processing with Industrial "M.U.S./c.l.e." reprinted in MMM C #2.

We mentioned the need for shielding. The development of simple canopy framework systems that can be locally manufactured, then covered with regolith, would be invaluable. Such canopies could protect stored fuel and other warehoused items that need to be accessed regularly, so that personnel could do these routine chores in less cumbersome pressure suits as opposed to hardened spacesuits. Such canopies could also serve as flare shelters out in the field at construction sites or at periodic points along a highway. An easily assembled (teleoperated?) space frame system with a covering that would hold a couple of meters (~yards) of regolith should be another design contest goal.

Modular Power Generation, Storage, and Heat Rejection Systems

This is a suggestion that NASA may well not bother considering. The initial outpost power generation and storage systems and heat rejection systems should be designed with modular expansion in mind. NASA will not be reflecting on the needs of expansion because its government mandate does not extend to expansion, unless space advocates force a change, even if "just to leave the door open for commercial developers who may follow." We think such activism is worth the effort.

Introducing Load-based Modular Biospherics

In our opinion, NASA's performance in developing life support systems has been hit and miss. Chances to incorporate a higher level of recycling on the Space Station were passed up in the name of up front economies, even though such systems will be absolutely vital on the Moon and Mars. To its credit, the agency does have the BioPlex project in full swing in Houston. But we worry that the outcome will be a centralized system that will work for the designed size of the lunar outpost, and not support further expansion.

The centralized approach to biospherics has a famous precedent: Biosphere II. We think centralized approaches are not the way to go. Instead, we should develop load-based decentralized systems. In this approach, wherever there is a toilet - in a residence, a workspace, a school, a shopping area, a recreation space, etc. there should be a system to pretreat the effluent so that the residual load on a modular centralized treatment facility is minimized. The Wolverton system is what we have in mind.

If all outpost modules with toilets have built-in pretreatment systems, then, as the physical modular complex grows by additions, the “modular biosphere” will expand with it. Expansion will not race ahead of the capacity of the contained biosphere to refresh itself.

Another essential element of modular biospherics is having plants everywhere. A phone-booth sized salad station will not do. Useful plants can be grown throughout the lunar outpost: they can provide additional salad ingredients and meal enhancers: peppers, herbs, spices, even mushrooms. Even decorative foliage and flowering plants help keep the air fresh as well as provide a friendly just-like-home atmosphere. Plants in front of any window or viewing portal would filter the stark and sterile barrenness outside.

Plants must not be an afterthought. We cannot long survive, let alone thrive as a species that hosts houseplants. We are a species hosted by the lush vegetation of our homeworld. We should never forget this. We cannot go with the attitude of “let’s build some cities, and a token farm here and there.” Rather we must go to build a new vegetation-based but modular biosphere which will then host our settlements.

City dwellers all too easily discount the farm. We have houseplants as botanical pets. That paradigm won’t work. Designing all habitation and activity modules to house plants as an integral feature will help allow the biosphere to grow in a modular way along with the physical plant. It will be a more enjoyable place to live as well.

NASA is unlikely to pay these suggestions a glancing thought. We hope that commercial contractors, whose long range plans are not limited by governmental myopia are more farsighted. Modular biospherics should be part of their business plans for any industrial settlements or tourist complexes on the Moon.

Teleoperation of construction & assembly tasks

So far we have been talking about architectural considerations that would prime any startup lunar outpost for expansion, no matter how restricted its mandated goals. But expansion, as well as original deployment, requires construction and assembly. To the extend that individuals in spacesuits are involved in this work, it will be dangerous and risky. Human manpower hours on the Moon will be expensive to support. Loss or incapacitation of just one person in an outpost construction accident would be a major and expensive one.

In order to maximize crew usefulness and productivity as well as health and safety as many tasks as possible should be designed for remote operation by persons safely inside the outpost or construction shack, or by teleoperation by less expensively supported people back on Earth. The latter option may be more technologically demanding but it is far more preferable. Every construction operation tele-controlled from Earth frees personnel on the Moon for things that only personnel on site can accomplish. The result is progress is surer, safer, and yet quicker. The outpost is up and running in less time, with everyone healthy and ready for real duties.

In the following article, page 7 below, we take up this fascinating topic of pushing the limits of teleoperation, surely a prime area for engineering competitions.

Teleoperation: getting the most productivity from our personnel on the Moon

By Peter Kokh

Tel•e•o•per•a•tion: remote control of the operation of untended equipment; radio-control

Relevance to Lunar Analog Research: using controllers with a programmed 3-second time delay, we can teleoperated various kinds of equipment in an analog "sand box" to attempt successively more difficult tasks, both to determine the practical limits of teleoperation, and to create training programs. We see pushing the limits of teleoperation as a key analog research program.

Actually, "teleoperation" is a relatively new word coined by space development writers. Even though we have been using it for two decades or more, it has escaped notice by those who are supposed to keep dictionaries abreast of the times.

The basic idea is do what we can, remotely, on the Moon, when human on site labor would be expensive, or dangerous, or best reserved for things which cannot yet be easily remotely performed. What makes tele-operation practical on the Moon, but discouragingly tedious on Mars, is the speed of light that governs remote control by radio. At that speed, there is a bit less than a 3 second delay between a teleoperators "joy stick" movement and the observation of the command being performed. Numerous experiments, many of them by enthusiasts, have shown that this small time delay is manageable. On the other hand, anyone attempting to teleoperate a rover or some other kind of equipment on Mars would have to endure a minimum delay 125 times longer, 6 minutes, and a maximum of around 40 minutes. Ho hum! Zzzzz!

Equipment on Mars, a whole fleet of it, in fact, could indeed be easily teleoperated from Phobos or Deimos, but the Mars Society resists the idea of setting up forward outposts on either Mars moonlet, as a "detour." That's their problem. Impatience always bites one in the but, one reason the opening of Mars must be more broadly based. But we digress.

Proposals for teleoperations on the Moon

Over fifteen years ago, it was suggested that mini-rovers on the Moon could be "raced" against one another over a prescribed course, the race watched on television, with the contestants paying for the privilege. The idea was to raise money.

More to the point, it has been suggested that equipment placed on the Moon could be tele-controlled to grade and prepare a site for a lunar outpost and once that was in place, the same or additional teleoperated equipment could cover it with regolith shielding, in advance of the arrival of the first moonbase crew. These would be time-consuming tasks for human crews. By tele-performing these operations, the crew would arrive at a Moonbase all set to go.

Beyond Site and Outpost Preparation

There will be "too much to do" for the small initial crew right from the outset. Nor will this change when the outpost begins to grow, not even when the first true settlers arrive. It is a truism of all frontiers, that there is always too much to do, that needs being done, than people to do it all. Sending people who are each multi-talented will certainly help. But that will not change the fact that there are only so many hours a day, and that there are limits beyond which driving individuals to put out ever more and more will backfire.

More to the point, there is a question of priorities. Somethings are too sensitive and/or too complex to be performed remotely. Hair-trigger responses are needed. On the other hand, there are tasks that are reasonably dangerous to perform, with a high risk of injury, or even death. These considerations give us a basis on which to decide when it is better to teleoperate, and when it is best to have an on site individual perform a task.

Add to that the financial considerations. Each man-hour of work, regardless of the pay scale, performed on the Moon, costs much more than that person's pay. You have to factor in what it cost to send that person to the Moon, maintain him/her there in good health, and to eventually (at least in the early phases of our open-ended presence on the Moon) return the person back to Earth.

It makes even more sense then, to find a way to teleoperate all risky and dangerous jobs, all routine and tedious jobs, and anything else we can do to relieve base personnel of any work we can so that they can get on with doing what only they can do. That way, the outpost, whether it is manned by four or forty or four hundred, can advance more quickly, will get more accomplished, thanks to its ghost army of teleoperators back on Earth.

Yes, we'd all like to see the lunar population to swell quickly to the hundreds, the thousands, maybe someday the hundreds of thousands. Doesn't taking jobs away from real people on location counter that goal? To the contrary, it advances it, because at each stage this pocket of mankind will be more productive, allowing it to grow faster, not just in industrial diversification and export output, but also in numbers. And the extra productivity earned by teleoperations, will make the settlement bottom line more attractive, less a target for budget cutters on Earth. When they arrive, their habitat space will be ready, thanks largely to teleoperated tasks.

What all can we teleoperate?

- Site preparation, grading, road building, excavation, shielding emplacement, repeatable construction and assembly tasks, deploying radio/microwave repeaters, deployment of solar power stations, initial prospecting surveys. (much more, especially in a given time, than Spirit or Opportunity can do), setting charges in road building, gas scavenging, preliminary routine prospecting surveys, lavatube exploration, etc. – i.e., many tasks that need to be done out on the surface, minimizing EVA hours by personnel in space suits.
- Tending agriculture installations, routine watering, weeding, harvesting, fertilizing, etc. – This is potentially the greatest time saver for teleoperation. In the Biosphere II experiment, it took the entire crew, working 10 hours a day, 7 days a week to produce a "starvation" diet, with all crew members losing substantial amounts of weight. We need to highly automate agriculture, and to teleoperated whatever we cannot automate, to free personnel on the Moon for those things only humans on hand can do.
- Many factory operations, especially dangerous ones
- Desk work, paper pushing, document processing tasks

The priority should be (a) to take care of as many out-vac tasks as possible which would be exhausting and cumbersome for people working in space suits, and not without real risk. (ab) exploration of subsurface voids – lavatubes. (b) inside operations which carry some danger. (c) routine, repetitive, and boring tasks to the extent that they cannot be automated. (d) utility and air/water treatment routine tasks, (e) routine inspection jobs, (f) some bureaucratic paper work, minimizing the amount of desk work that has to be done on location. (g) when the time comes, the bulk of routine teaching assignments. Again, one must keep in mind, that teleoperations are to prepare for humans to settle in and live comfortable fulfilling lives.

What we can do now

If we succeed in putting together an aggressive Lunar Analog Research Station program, one thing we don't have to do is prove the value of human-robot teams in field exploration. We have already made that point in the Apollo program years. So practicing lunar geology is not a high priority, nor is field exobiology. The M.A.R.S. analog stations have done great work in this area. Again, we've already made that point almost forty years ago.

On the other hand, the Mars people have no need to demonstrate teleoperations skills, as Mars much greater distance, from 125 to 400 times further from Earth than the Moon, makes teleoperation impractical – unless they want to come to their senses and realize how much faster the Martian globe could be explored with fleets of minirover probes teleoperated from just above, from shielded stations on Phobos and/or Deimos.

Teleoperation with a 3 second time delay has been demonstrated many times, but mainly in the "driving" of rovers. More complex tasks such as site preparation and shielding emplacement via teleoperation have not been demonstrated. These are challenges suitable for college level engineering teams, and the demonstrations could be done at an analog station. What we'd need for terrain, at least in the area where we would be teleoperating is a physical analog of lunar moondust or regolith. The elemental and chemical composition would be irrelevant. The mix of particle sizes and the behavior of the mix in handling would be essential. It would be in NASA's interest to fund creation of such a site, whether a sandy gravel mix native to the area was further transformed to meet the experiment constraints, or whether the faux regolith was prepared elsewhere and trucked in.

Once site preparation and shielding emplacement techniques were demonstrated, we could ramp up the challenges to include road construction and many other chores we'd prefer not to have done by humans in cumbersome spacesuits, exposed to cosmic radiation. (ab) teleoperated exploration of a nearby lavatube would be possible in some of the sites under consideration (Bend, OR; El Mapais National Monument south of Grants, NM, Craters of the Moon National Park in Idaho). But we could run such tests at one or more of those locations whether we had deployed an analog research station nearby or not. We could also try to develop teleoperable greenhouse systems, water recycling systems, ACC; even though we don't need to demonstrate human geology field work, we could demonstrate teleoperation of prospecting probes.

The possibilities are many, and will grow with the complexity of our outpost, and its continued growth.

Teleoperators on Earth

These people, whether unpaid volunteers, or paid assistants, should earn status as "lunar pioneers." For even if they never personally set foot on the Moon, the fruit of their work will be in evidence throughout the area where human settlements spread. **<MMM>**

MMM #199 - OCTOBER 2006

Candidate Lunar Analog Station Sites

By Peter Kokh

For the sake of argument, let's pretend that money is not a problem. The Moon Society has decided to find a location for its own Analog Research Station in a more geologically and morphologically appropriate area. What locations might make a short list, if we were constrained by logistical practicalities to the area of the continental U.S., "the lower 48" states?

Our first search turns up four promising areas, all in the Western States, each offering extensive lava flow sheets and attendant lava tubes:

El Mapais National Monument just south of Grants, NM off I-40, air hub Albuquerque, NM at 80 miles

Craters of the Moon National Park in Eastern Idaho, air hub Salt Lake City, UT 270 miles. Boise regional 184 miles. Pocatello feeder service at 80 miles away.

Snow Canyon Sate Park outside St. George, Utah 121 miles from Las Vegas, 300 from Salt Lake City and 220 miles from the Mars Desert Research Station. Feeder service into Cedar City, 60 miles NE of St. George

Bend, Oregon – in the high desert just east of the Cascades. Closest air hub: Portland 185 miles

EL MAPAIS NATIONAL MONUMENT, NEW MEXICO

http://www.nps.gov/elma/

Just considering the logistics, accessibility by road, rail, and air the El Mapais site in New Mexico takes the clear edge. And logistics are very important: getting people and supplies in and out easily and inexpensively, and quickly. However, The Moon Society has no current members nearby, though four former members were last listed in Albuquerque. If one of them could be reactivated to assist crew members coming & going, that would help.

First, however, we would have to assemble a small team, 2-4 persons at most, who would have to go to the area, and, equipped with detailed topographic maps, individually check out various spots. We would prefer to be on BLM public land just adjacent to the monument, and have approved access to a lavatube. It would also be desirable to be off any of the regularly used tourist roads, tracks, or trails.

The El Mapais site does have the slight advantage of being within a few hours drive of Spaceport America being built by Virgin Galactic for tourist suborbital hops in the area north of Las Cruces. But then, visitor traffic is _not_ something this writer and former MDRS crew commander sees as a plus. Visitors are a big simulation-disturbing distraction.

CRATERS OF THE MOON NATIONAL PARK, IDAHO

http://www.nps.gov/crmo/

COM NP is not appreciably further from Salt Lake City than the Mars Society's desert station in Hanksville in south central Utah. It's just a question of going north instead of south. An asset would be personnel on the ground in Salt Lake City, who might be willing to facilitate crew arrivals and departures, and do scout work for sourcing supplies in SLC. By the way, I personally love SLC! Nestled up against the awesome Wasatch Range, it has no rival for scenic setting.

Boise is closer, but may not enjoy as favorable round trip airfares from other points as does Salt Lake City. Seven former members are from the Boise area. There is feeder service into

Pocatello Regional Airport, an 80 mile drive from the Park, via SkyWest, serving United and Delta passengers) from both Boise and Salt Lake City.

Again, as with El Mapais, we'd have to spend some time looking for just the right spot, as noted above. William Fung-Schwarz, Artemis Moonbase Sim 1 Health & Safety Officer, who lives in Salt Lake City, has already identified "seven places to start looking" on the basis of aerial maps of the region. Again, as with El Mapais, the area receives appreciable tourist traffic, a plus at the visitor center, a minus if they interfere with out operations or intrude upon our area of operations too closely.

SNOW CANYON STATE PARK, UTAH

www.stateparks.utah.gov/park_pages/scenicparkpage.php?id=scsp

www.stateparks.utah.gov/press/default.php?DateCode=43

A short drive NNW of St. George, Utah, this park does have lavatubes and deserves a visit. St. George is on I-15, 121 miles (2 hrs) from Las Vegas to the south, and 300 miles (5 hrs) from Salt Lake City to the north.

In February 2005, on my way back to SLC from my first tour of duty at the Mars Desert Research Station, I had time to pay a personal visit to one lava field area just west of Fillmore, Utah, 150 miles SSW of SLC on I-15, and just 3 hours from the Mars desert station. But on first inspection, the site did not seem at all suitable and had no lavatubes nearby. The area's terrain is very rugged and "clumpy", difficult to traverse on foot, impossible in a vehicle without first grading a roadway. Plus, it was heavily vegetated with bushes and shrubs.

BEND, OREGON www.oregonl5.org/lbrt/l5ombase.html

Bend was home of the former Oregon Moonbase of the Oregon L5 chapter of the National Space Society. There are three great pluses to this location. One, we have a sizable critical mass of very knowledgeable volunteers in the Oregon L5 NSS chapter, based in the Portland metropolitan area. Two, if we were able to re-secure the lease that the Oregon L5 chapter had on the site some 5 miles northeast of Bend on Bend city water works land, that would be great. The pair of lavatubes there has been thoroughly investigated with both geological and engineering reports. I had a personal guided, very thorough tour of both tubes in 1992 as the guest of Bryce Walden and Cheryl York of the Oregon Moonbase team.

The former Oregon Moonbase site outside Bend is no longer available, but there are many other lavaflow-lavatube sites nearby to Bend.

With the Oregon Moonbase - Oregon L5 Society team still intact, and actively partnering with the Moon Society, we have ready volunteers to visit the other site options and prepare a report on the basis of which a decision might be made.

But that we have a critical mass of supporters three plus hours away, is the biggest plus, and certainly puts Bend at the top of the list. If and when we decide that the Moon Society needs its own Analog Station in an area geologically and chemically and landform-wise analogous to lunar sites, the Oregon team could have all its ducks in a row. Meanwhile, we'd have to investigate the other two general areas from scratch.

So as of this point in our investigations, the Bend, Oregon area seems the candidate "site to beat." But, pending a field trip to investigate, the handiness of the Snow Canyon site to both Las Vegas and Salt Lake City, as well as to the Mars Desert Research Station, makes that site a potentially strong challenger. Las Vegas has been the preferred site for a Moon Society Visitor Center, and that is a consideration also.

See Project Leto: www.moonsociety.org/projects/leto/ (project now defunct)

PHOENIX-TUCSON AREA

Since this report, and considering other factors such as proximity to an active Moon Society Chapter and to universities doing relevant research, the Phoenix-Tucson seems very attractive. We have desert areas, some more sparsely vegetated than others, a volcanic area in the Superstition Mountains East of Phoenix. However, we have not been able to locate candidate areas. This would take an "exploratory expedition."

SPACEPORT AMERICA

This area also has some less vegetated stretches. Its main attraction is that it would be a good location for a visitors center. Such a center would need to be designed with care to allow visitors to “see, but not be seen” by crew members. Using web cams and duck-blind trails, carefully constructed, this separation is possible.

THE CHICKEN OR THE EGG

At this stage of the game, we need people “on the ground” to identify a number of candidate sites, then send a team to check out each of them. At the moment, we have neither for any of the above locations.

EXPENSES

There are expenses, hopefully volunteered, for local people to scout out candidate sites. Then there is the expense of sending a team to the area (and probably to several areas.) But that is just the beginning. If the site can be secured from the Bureau of Land Management at no cost, as was the case for M.D.R.S., there is still the cost of erection of a facility, even of one that is “phased in” slowly over time.

MEANWHILE

The Society is looking at a fresh paradigm, one which would not involve an expensive MDRS type operation, but which would involve many canters, each under-taking a share of analog research projects, close to where the researchers live and are based, and close to supporting institutions. This plan may include research already underway at select institutions. **<MMM>**

MMM #200 - NOVEMBER 2006

A Lunar Analog Station Program can pave the way, if well-focused

By Peter Kokh, David Dunlop*, Michael Bakk**

* Moon Society Director of Project Development

** Captain of the Calgary Space Workers who are developing the prototype modular analog outpost

[Our 3rd attempt at unzipping the L.U.N.A. Acronym]
“Luna Underground Nucleus Analog”
“Lunar Underground” - That’s us, an underground movement! Plus we will model **shielding**, shielding architectures and shielding emplacement options as well as monitor the thermal equilibrium benefits of an “underground” (under a regolith blanket) facility.
“Nucleus” - we are modeling not a self-contained unitary module good only for extended science picnics but the kind of modular outpost that could become the nucleus of open-end expansion into a settlement
“**Analog”** - we aren’t trying to be exact. We need to pick our battles, getting the most bang for the buck.
We had tried twice before to come with an unzipped “Luna” acronym. Most recently, in MMM # 194 April ‘06 we suggested ‘Lunar Underground Network Accelerator.” In MMM #148 Sept ‘01, “Lunar Utilization & Necessities Analog.” We like the new reading best.

A Summary of where we are at in our planning

As stated in the MMM #195 article above, an analysis of research & development demonstration needs shows that the Goals of a Lunar Analog Station are quite different than those of the various Mars Analog Stations:

- We do not need to demonstrate the usefulness of human exploration of the Moon. Apollo did that well.
- We will not be demonstrating microbiological forensic techniques that might prove the Moon once had or might still have living microorganisms – we are all amply convinced by the Apollo and other evidence that the Moon is totally sterile
- Nor do we have to demonstrate geological techniques that might reveal the scope of Mars once much "wetter" past – the evidence that the Moon has always been bone dry is overwhelming.
- We don't have to model a first visiting crew exploration vehicle. NASA began that with Apollo and will continue that with the lunar outpost program
- **What's left for us to do?**

√ **NASA's plan was limited from the outset**

√ **It is vulnerable to budget cutbacks**

NASA's plan is for a small crew outpost with limited capacities for growth and to support demonstrations of production of various elements and of lunar appropriate building materials. The agency's plans are very vulnerable to unrelated budgetary pressures, owing to the black hole of conducting an unforeseen war.

Biological Life Support Research has been cut

Already NASA has discontinued the BioPlex project in Houston and stopped continued funding for the NSCORT program at Purdue University. Both of these programs were aimed at finding practical ways to deploy closed loop life support systems supported by plant growth and food production and waste treatment systems. There is no question in anyone's mind that a permanent presence, let alone true settlement, can be realistically supported on the Moon without coming very close to "closing the loop."

This means that it is up to efforts outside NASA to make continued progress in this area. Actually, the NASA plan was so limited from the outset, that it has always been up to us.

You can't do biological life support in a closet

Life support cannot be approached as an afterthought. It has to be designed into every module and connecting corridors.

We will be studying the modular habitat prototype being designed and built in Calgary, Alberta, and to be deployed in the Drumheller, Alberta badlands, looking for opportunities to integrate biological life support functions. Biospherics must be approached in a modular fashion, so that as the pressurized interconnected habitat complex grows, the biosphere will grow with it, hand in glove, step by step. If you are designing a limited outpost with expansion as an afterthought, such an architecture will seem irrelevant, or not worth the cost.

Shielding cannot be an afterthought

Many NASA illustrations pay homage to Bob Zubrin's double tuna-can design, become so familiar to all of us as the architecture of the Arctic and Desert Mars Research Stations in Canada and Utah. The high vertical profile makes shielding difficult. Zubrin seems to dismiss radiation shielding as unnecessary. But if we are going to move beyond short tours of duty towards real permanence, we have to rely on more than Release Statements that do not hold NASA responsible for radiation damage.

Unaddressed are the major thermal equilibrium benefits of shielding. It pays to design an outpost in a "ranch style" low profile format to make deployment of regolith shielding easier. Shielding can be deployed directly as loose regolith, or as bagged or sintered regolith (blocks) for easy removal should access to the hull or a need for expansion make it necessary. We need to experiment with teleoperated shielding deployment systems, so that a landed but unoccupied outpost can be pre-shielded and ready for occupancy by the first crew. We can demonstrate a variety of such systems.

Modular Architecture, Shielding, and the Media

Granted, the Zubrin double tuna can (DTC) design has been a big hit with the press. It looks like the otherworldly mechanical "visitor" that it is. On the other hand, it does not look like "module one" of a future settlement, and that is the concept that what we want the public and the media to grasp. **We must sell modularity**. On the surface, that will be an easy task. But if we use reconditioned travel trailers and other adapted but identifiable terrestrial artifacts, that appearance may detract and distract from the lesson we are trying to get across.

However, if we shield the complex with simulated regolith, sand bags, or bags of mulch, whichever is more practical, we'll get our lesson across. A shielded modular complex will look much more serious than the DTC. The idea that we are planning to stay on the Moon, not just explore it and go back home, will be clear. We can make show how the shielding blanket on the Moon will perform the same services for us as does our atmosphere blanket. That we can make ourselves at home on what looks like an inhospitable world will begin to sink in. Daydreams of being stationed in a livable lunar outpost will start to look more romantic than being confined to a DTC on Mars.

Resource use should not be an afterthought

The well-advertised NASA In Situ [on location} Resource Use demonstration of oxygen production is still on the Lunar Outpost manifest. But by deciding that lunar oxygen would not be used for the lunar ascent vehicles, NASA effectively put it on the budgetary chopping block.

Lunans will not live, let alone thrive, by oxygen alone!

A lunar analog research station in basaltic terrain could get involved in cast basalt use demonstrations. Cast basalt tiles and abrasion resistant materials handling components are now being produced in several locations. If there is anything that is priority #1 it is to test regolith handling systems, and if we need cast basalt products for that, that fact would but cast basalt demonstrations ahead of everything else, perhaps even ahead of oxygen, as all other ISRU experiments will depend on regolith handling. Cast basalt products can replace many original outfitting items in the habitat module complex: flooring: table, desk, counter, cabinet tops, wall tiles, decorative items and objets d'art.

Other building materials to experiment with are glass-glass composites (currently just one ice-cube sized laboratory sample), steamed fiberglass cements, fiber-glass-sulfur composites, sintered regolith products, sintered iron fines products, sintered regolith products. The first goal will be to be able to demonstrate the feasibility of location (on the Moon) outfitting of inflatable expansion modules. Demonstration of the production of pressurizable modules from simulated lunar building and manufacturing materials would come next.

Experimentation with lunar sourceable metal alloys, as critical as it is, is best done elsewhere, because of project complexity and thermal conditions, and the expertise needed. In all these ISRU experiments, we must keep in mind that laboratory scale experiments, however successful, do not prove that production-scale operations are feasible. Chemical engineers will be much more help-full than chemists, for example. Laboratory scale experiments done elsewhere can possibly be demonstrated on a larger scale at analog facilities.

Power Production & Storage

NASA and many lunar enthusiasts are hell-bent on setting up shop at the lunar South Pole. To quote lunar planetary scientist Paul Spudis,

"Although polar ice is important, it is not a requirement to successfully live and work on the Moon. The poles of Moon are primarily attractive due to the near-permanent sunlight found in several areas. Such lighting is significant from two perspectives. First, it provides a constant source of clean power and allows humans to live on the Moon without having to survive the two-week-long lunar night experienced on the equator and at mid-latitudes. Second, because these areas are illuminated by the Sun at grazing angles of incidence, the surface never gets very hot or very cold. Sunlit areas near the poles are a benign thermal environment, with an estimated temperature of about -50° ± 10°C

http://ww.thespacereview.com/article/740/2

Now if you are younger than fifty, the expression “Kilroy was here,” may mean nothing. This was a WW II (and perhaps older) way of “tagging” a place to say that a Yankee (an American) had been there. Now if all that you need to die happy is to know that we put up a “Kilroy was here” outpost at the Moon’s south pole, then Spudis’ vision will thrill you to the core.

But if by “lunar settlement” you mean a global presence of humanity on the Moon, then the lunar polar “gesture” (which is all it is) will be but “a tagging event.” Avoiding the Nightspan Power Problem and the Dayspan Heat Problem is exactly what we must not do!

As NASA has chosen not to bite this bullet, demonstrating various ways that enough excess lunar solar dayspan power can be stored to get us productively through the nightspan is a priority task for Lunar Analog Stations. That said, simulating the 14 day 18 hour long dayspan and same length nightspan will be much easier to do inside a closable structure such as a large aircraft hanger or high-ceiling warehouse than anywhere outdoors. For this kind of experimentation and demonstration the geological and/or physical characteristics of the host terrain will be irrelevant.

Power storage options include storing waste water at a usable head height, flywheels, fuel cells, magma pools, and other devices. Yes, a nuke would do, but we think it is important to demonstrate any other non-nuclear “backup” options that would do the trick, and which would be easier to scale up or down to the power requirements of a growing lunar beachhead.

The other half of the equation is demonstration of how well various types of lunar outpost operations can be managed sequentially to take care of the bulk of energy-intensive operations during the dayspan, and the bulk of labor-intensive energy-light operations during the nightspan. Such a regular change-of-pace rhythm is bound to become a welcome mainstay of lunar culture.

Ergonomics Demonstrations

The Mars Society missed an obvious opportunity for an ergonomics layout study, by outfitting the interior of its second habitat, the Mars Desert Research Station, with essentially the same floor plans, upper and lower, as in the Arctic station which was built first. Of course, there were time and money benefits to taking a bye on the ergonomics opportunity.

The independent-minded European Mars Society will be designing the interior of the EuroMars with a clean slate. They are happily immune to the expected criticism. This unit will be just a tad taller, by just enough to squeeze in a third floor. They will be incorporating more opportunities for customization of personal quarters, euphemistically called “staterooms” as well as morale boosting perks like a spa tub, and exercise area. The objection that pioneers should feel privileged to “rough it” just doesn’t cut it. High morale translates to productivity and safety, and those are far more important considerations than penny-pinching economy. One must keep in mind that the Mars explorers will be away from home for two or three years, factoring in the long travel times to and fro.

A modular outpost gives much more opportunity to vary living and working arrangements and their mutual proximity or isolation. A modular outpost, particularly a “practice” one, can have its layout plan “shuffled and reshuffled” until the happiest disposition is found. A consideration, one that does not easily arise in the Mars Hab instances, is finding the best vectors for expansion of the various kinds of facilities: residential, energy generation, workshop, laboratory, fabrication shop, greenhouses, exercise and recreation facilities, and what-ever other modular facilities may be needed to “break out of the outpost trap.” Developing a site plan with options for expansion must be part of the site selection process.

A mix of hard body and inflatable modules will also yield valuable lessons. The option of adding new modules fabricated out of simulated lunar-processed building materials such as glass composites or fiberglass reinforced concrete is also attractive.

Lunar Analog Outposts will be innovative

It may seem to the casual observer in the public or the media that the exercises at the two operational Mars Habs are getting repetitious. Until you take a close look, all the geology experiments, the biology experiments, the GreenHab experiments, and the human factors studies seem to produce nothing new. Take it from one who has been on two MDRS crews: that is definitely not the case. New things are being learned crew after crew, and I remain a staunch supporter of the Mars Analog program. But the illusion or repetition dogs the program.

Next year, there will be a 4-month long exercise by one crew at the Arctic outpost on Devon Island. That will definitely test the reliability of utility systems, at a location that is logistically quite isolated, as well as be a superlative opportunity for human factors studies. Now if the Mars Society would embrace the projects to the Mars Home Foundation which wished to build a demonstrator Martian Village out of materials available on Mars, that would be really helpful.

In contrast, the Lunar Analog Station programs will have no shortage of new things to do and try and test. The clear sign of progress will work to keep the media, and the public interested, as well as to educate them on the possibilities of human settlers making them-selves permanently at home on the Moon.

Lunar Analog Outposts and Tourism

When the Moon Society was founded in July 2000, the flagship project announced to celebrate the society's birth was Project LETO [Lunar Exploration & Tourist Organization] conceived of as both a tourist facility and as a research station. On first glance, this would seem to be a marriage made in heaven. But having four weeks of experience at MDRS in Utah, I'm convinced that research is best done without the visual or actual interference of curious onlookers. Now in the 2005-2006 field season we experimented with first one web cam then as with as many as six. This works well, and does not disturb research activities.

What does seem most important, even to the point of being sacred, is to preserve the illusion that you are on Mars (or, in our case, on the Moon) as the illusion helps one take the experimentation and/or exercise seriously enough to ensure superior results. In short, it does not disturb research if visitors or tourists can watch so long as they are out of sight of the researchers.

One way to keep the required separation is the use of web-cams. What about an analog of a duck-blind? That might work for outdoor activities, but without a great number of such blinds, we couldn't ensure visitors that there would be anything worth observing on a regular basis. Web cams or remote TV cameras would seem to be the better answer. Actual supervised "do not touch anything period!" tours could be conducted when the facility was not occupied.

At MDRS, media visits are allowed, but scheduled by program headquarters to minimize interference with MDRS activities. Nonetheless, interfere they do.

Visitor access is important. We will have our faithful followers and enthusiasts who will want the high of seeing this glimpse of the future for themselves. What we can't do is make the analog outpost a zoo exhibit! or create conditions where the crews feel that they are zoo animals. But growing our constituency is of primary importance as well. So how we can best satisfy the needs of both the various crews and the faithful/curious with-out shortchanging either is an area that deserves much forethought and should be part of the original site plan.

The commercial connection

Whenever or wherever the brand or supplier of any needed equipment is not crucial, the opportunity to have the equipment donated "by the official refrigeration supplier to the Moon Society Lunar Analog Outpost" etc. (for sake of example) should not be passed over lightly. We will always have less money than we need. And when performance or specifications are crucial, all the more reason, for advertising punch to approach a manufacturer or distributor for product donation or free lease.

We have talked many times about the "spin-up" paradigm, much more powerful than the "spin-off" system in place for decades. In spin-up, an entrepreneur develops a technology or product which happens to be needed on the frontier, precisely for the potential "here and now profits" from any terrestrial applications. As we succeed in encouraging entrepreneurs to take this route, they can test and showcase their products at an analog moonbase location, as an effective advertising ploy. The donation of a model, when it can be integrated into the analog moonbase operations, would be a big plus.

We may be the small guys in town, but we have the bigger dreams, the more powerful dreams, the only dreams that make sense in the long run. There may be several analog lunar station operations. Between us, we can leverage our way to reality. **<MMM>**

Analog Outpost Site **Options Continued**

When what really matters is "moondust behavior" not "moonscape appearance"

Looking for a "physical" moonscape analog location for a Lunar Analog Research Station

By Peter Kokh

In MMM #198, p. 11, I noted that to demonstrate the teleoperation of equipment needed for moonbase site preparation and for emplacement of regolith shielding over the base, for road construction, mining, etc., it was not a chemically and mineralogically analogous site that we needed. Whether the surface material was basaltic lava flow as in the lunar seas or maria, or similar to highland deposits, would be quite irrelevant. What we need is a pulverized rock and rock powder mix of whatever kind of minerals, so long as the mix of particle sizes was the same as what we find on the Moon, and so long as the handling characteristics are reasonably similar.

Now at first that seems to open the door wide to a long list of potential sites. But alas, no site on Earth has a surface like moondust, either highland or mare. What we have to do, is find a fine gravel or sandy site and then modify it by importing particles in missing sizes and mixing until we have "a mix that works".

This is important, because when push comes to shovel, how the material behaves may affect the degree of confidence we have in the equipment we wish to teleoperate in handling this faux regolith. Now we could just buy a hundred or so truckloads from NASA's source for lunar simulant, but again, we do not need the chemical and mineralogical similarity to moondust, only the physical similarity.

Can we produce this at less expense, economically enough to be able to cover a substantial area with it (an acre or so may do for starters.) I don't know. But it should not be anywhere near as expensive to prepare as the original MLS-1, Minnesota Lunar Simulant 1. In July 1987, I got to see how this handy material was made in a laboratory of the University of Minnesota in Minneapolis, under Dr. Paul Weiblen (still a faculty member but retired). The process began with solid rock quarried from an exposed layer of unusually Titanium rich basalt in a cliff that runs SW to NE in Duluth, Minnesota.

But as the chemical makeup and mineralogy is irrelevant, and we are interested only in the physical properties of the mixture and its behavior in handling, we should be able to start with already pulverized material and then modify it with finer and coarser amendments as needed.

One of the challenges is to get the material to handle similarly. Unlike weathered rock powder on Earth, lunar rock powder retains the angular shapes that come from an origin as impact debris. This material compacts together to hold its shape and hold a slope much better than sand, for example. As to the electrostatic properties that cause moon dust to so insidiously infiltrate mechanism and lubricants, that is a separate problem NASA must solve for all exterior equipment. We need concentrate only on teleoperating regolith handling equipment.

Appropriate Reading

Lunar Regolith and Fragmental Breccias
http://epsc.wustl.edu/admin/resources/meteorites/regolith_breccia.html

Lunar Regolith Structural Properties
http://www.asi.org/adb/m/07/particle-structure.html

Another challenge is how inappropriately our transformed stuff acts when wet. The Mars Desert site in Utah becomes slippery mud when wet, and that simply won't do. Thus we may want a very dry desert site. The world's driest desert, the Atacama in northern Chile, however, is logistically out of reach. The driest U.S. desert is the Mojave. It includes the south tip of Nevada (Las Vegas), the NW corner of Arizona (Kingman) and large adjacent areas of southern California including Death Valley. Another solution would be a large covered area under which to experiment in ever-dry conditions.

Starting points - plain sand?

Sand particles range in diameter from 0.0625 mm to 2 mm. The greater portion of the regolith ranges from 0.045 to 0.010 mm, smaller than the largest sand grains. Add a lot of talcum powder?

Next we need to simulate the cohesiveness of regolith as demonstrated in its ability to hold both high angle slopes and bootprints. Adding very small size glass and ceramic smithereens may help.

Point of Diminishing returns

A lot of experimentation, tempered by financial practicality, may be needed to produce a close enough match for handling demonstration purposes. There will come a point in trying to assemble a regolith-like mix that the benefits of further amendments are not worth the cost. So our faux regolith will be inaccurate but "good enough."

Cosponsors and/or Clients

Depending on how good a physical analog of moondust we are able to create, NASA may find it useful in ways its regular lunar simulant is not. They may well want to test various kinds of equipment at our "physical analog" moonscape site. Various private companies interested in supplying equipment to NASA may also wish to use such facilities.

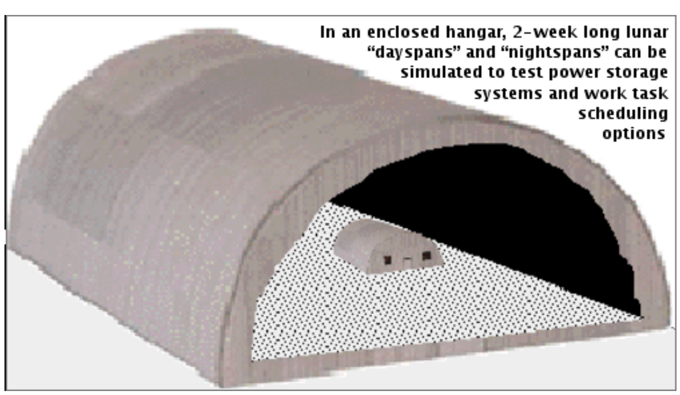
So there is some incentive to go ahead on such a front. For now, we need to keep brainstorming the idea, including the kinds of test equipment that will verify or "flunk" our faux moondust process and product.

Mirror Site for Tourists

Kids of all ages like to feel stuff and see how it behaves, physically. The chemical and mineralogical makeup is a moot point that impresses them not. A large play area of our physical simulant would be a great addition to a Lunar Tourist Center especially where there are lots of kids, theme parks over gambling oases. But this is a feature that could be replicated at many locations, licensed to a large chain of theme parks rather than to just one.

An Experiment in process

The Calgary Space Workers have accepted NASA;s Centennial Challenge to produce so much oxygen from so much simulant in such and such a time frame. Before trying their process on the official JSC-1a simulant, they will attempt to make their own simulant expected to be very close to the official one. **<MSJ>**



MMM #201 - DECEMBER 2006

MODULAR BIOSPHERICS

Making the most of pressurized pedestrian & vehicular corridors.
A system to model in Lunar Analog Stations

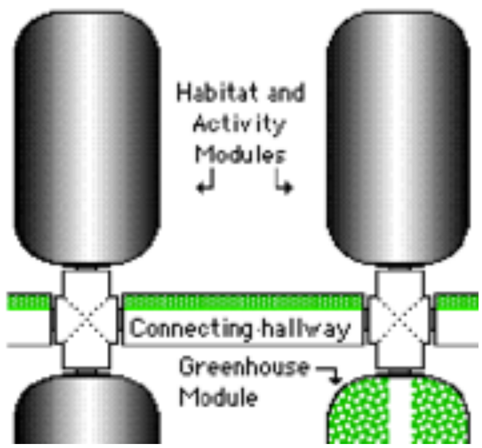
“Living Wall Systems”

By Peter Kokh

“A living wall is a vertical garden. Plants are rooted in compartments between two sheets of fibrous material anchored to a wall. Water trickles down between the sheets and feeds moss, vines and other plants. Bacteria on the roots of the plants metabolize air impurities such as volatile organic compounds.”
http://en.wikipedia.org/wiki/Living_wall

While this is the definition in the most technical sense, experimenters have made living walls in which plants are in pots anchored to a wall in a staggered pattern. They have also found other ways to keep them properly watered, fertilized, and to recycle the drainage water. The illustration top right is an example of the first approach, the illustration bottom right of the latter.

In a modular outpost, there will be connecting tubular passageways for pedestrians and small carts. Their curved walls offer an opportunity to increase the overall biosphere mass of a lunar outpost (real or analog) by integrating a living wall feature along one side, for the whole length of (each) hallway. This will be in addition to the biomass contributed in any Greenhouse modules and any in the habitat and activity modules themselves.

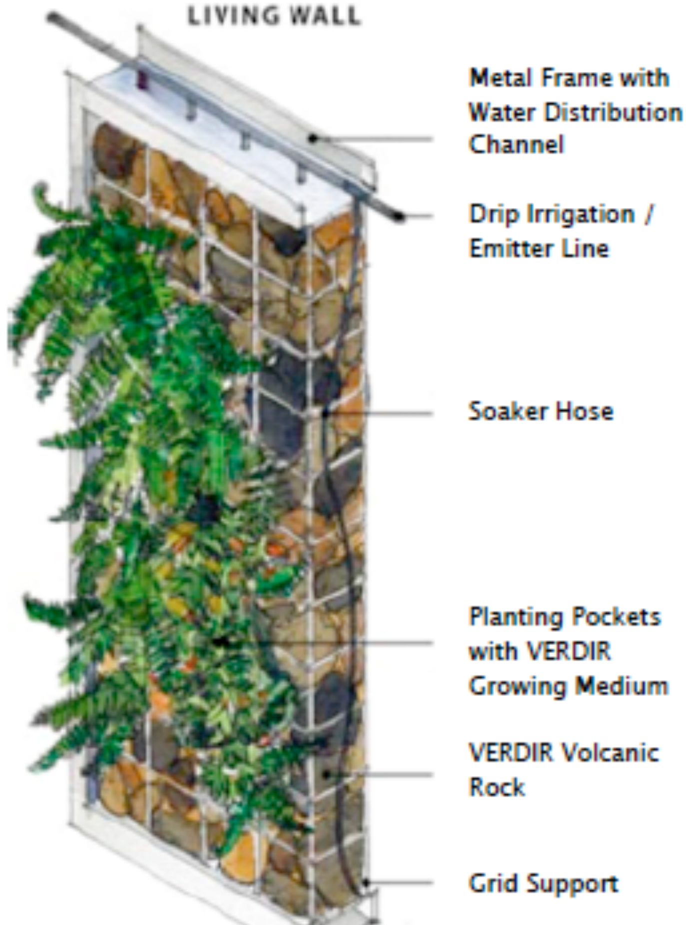


In a larger Settlement, pressurized Roads could have living walls to each Side, and down the middle, to separate traffic flowing in opposite directions, boulevard Style.

If we continue to think in terms of floor space, then we will be put in competition with the plants we depend on - not a prescription for success. But plant areas can make use of otherwise empty wall space.

“Waste no opportunity to include more plant life, want not for your next breath” to paraphrase an old saying.

If we are talking about an open-ended installation (again, either on the Moon or at an analog research site) by adopting a policy that no wall should be idle, we guarantee that the modular outpost grows, a modular biosphere grows with it, neither outstripping the other. Now can there possibly be a better arrangement? Yet so far all biosphere experiments seem to be of set size, not designed to grow in modular fashion. The non-modular set-size approach tends to be an effective predictor that the installation will have no future.



from

http://www.verdirsystems.com/html/living-walls.html

The above shows a technical approach.

Many Living Wall installations use a system of staggered planters and integrated water features to accomplish the same ends in a more natural and beautiful fashion.

Plants to choose from

There is a wide variety of plants that provide lush green foliage while cleansing the air of toxins (to prevent "sick-building syndrome") and increase the amount of oxygen, maintaining a fresh, clean atmosphere inside.

Dr. B. C. Wolverton, doing the research for NASA, identified a dozen common house plants easily available that cleansed the air, including: gerberra daisy, bamboo palm, spider plant, marginata, mass cane, spathiphyllum, Janet Craig, and ˇEnglish Ivy – published in the pamphlet "Plants for Life: Living Plants Vital In Filtering Contaminated Air – a NASA pamphlet published more than fifteen years ago.

Now Dr. Wolverton has published a much more comprehensive treatment in the book, "How to Grow Fresh Air: 50 Houseplants that Purify Your Home or Office" – Penguin Books ISBN 0.14.02.6242.1.

Living Wall installation, Baltimore, MD. This 110 sq ft (10 sq m) wall filters all the air for its 7,500 sf office building. Notice the ornamental character of some plants chosen

Living Walls as Graywater Purifiers

www.holon.se/folke/projects/openliw/openlev_en.shtml

"By growing plants in a porous wall [a special adaptation of the Living Wall concept, read on], you get both an efficient space use by vertical plant growing and purification of the percolating water, which can be grey-water." (Graywater is water from sinks, tubs, and showers, and previously treated blackwater from toilets.)

"The hollow parts of the stones are filled with inert materially like gravel, LECA-pebbles, perlite or vermiculite. The stones are placed so the water will percolate in zigzag through the wall. Bacterials in the porous material break down organic pollutants. The water trickling down through the wall will nourish the plants at the same time as it will be purified The plant roots will grow into the inert material and extract nutrients from the water. Over the pebbles, a film of bacterials will grow. After consuming organic material they release the nutrients in the percolating water. The plants will take up the nutrients and subsidize the bacteria with sugar from their photosynthesis.

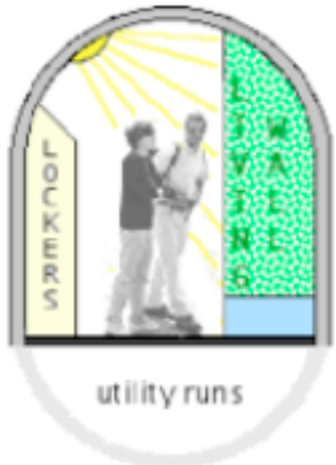
"By this, you get both vertical growing & grey-water purification. Therefore, the efficiency of the purification is dependent on the amount of solar radiation reaching the plants in the wall." [web source cited above.]

Air Circulation Systems

"Active walls'" are also integrated into a building's air circulation system. Fans blow air through the wall and then recirculate the refreshed air throughout a building. These indoor living walls help prevent and/or cure what is known as "sick building syndrome "by increasing air oxygen levels .

Integrating Water Features and Fish

Some Living Walls integrate fish ponds at the foot of the wall as part of the system where trickling water collects before it is pumped back up to the top of the wall.' The foliage purifies the graywater, digesting the dissolved nutrients. Thus a living wall can be an integral part of a water purification and reuse system, not just fresh air.



Above: Cross-section of a hallway corridor in a modular lunar Analog Research Station – or in an actual Lunar Outpost

Decorative Options

Ir is easy to work in rocks and/or decorative planters, sculptures and other objects into a living wall system. These can be design accessories or fully functional parts of the plant holding and water irrigation systems. A living Wall is something to be designed to suit taste as well as to serve function.

In a modular (analog or real) lunar outpost, each hallway could boast its own design, creating a more interesting working an living environment as well as a fresher, cleaner, healthier one.

You can go high-tech, but this is not necessary, and the cost-benefit ratios of a high-tech approach are probably not great. Low tech is always better if it works.

Using all Opportunities to increase biomass

We tend to make the mistake of describing living space volume in terms of square footage of floor space only, neglecting the opportunity walls provide. Counting all surfaces is the secret of packing a bigger biosphere into a smaller space: using walls, and even ceilings!

It is important, if we are going to bring the biosphere truly inside, to build our environment with mold-resistant surfaces. This means giving careful consideration to materials and surface coatings, as well as due humidity control and ventilation.

Sunshine, or its equivalent

Proper light must be brought in by light pipes, clerestories, or grow-lamps: a separate, related topic.

Purposes of Living Wall Systems in an Outpost

- purify and freshen air; purify graywater
- provide lush greenery, color, interest
- provide herbs, spices, berries, etc. and last, but not least,
- to psychologically “reencradle” crews in a minibiosphere **<MMM>**

The MexLunarHab Project

Report by Peter Kokh

Jesus Raygoza, who founded the National Space Society chapter in Guadalajara, Jalisco, Mexico in the 1980s and who more recently has been the principal proponent of the “MexLunarHab” project (**MLH)** has been a recent house guest of Moon Society President, Peter Kokh.

Naturally, the topic of Analog Moonbase Stations and simulations has been a dominant one. However, Jesus [pronounced hayZOOS] is also a key figure in the shaping the future of the recently created Mexican Space Agency, **Agencia Espacial Mexicana** (**AEXA**), with an initial budget of only $2 million. To put that small amount to best use, leveraging it to grow and have the greatest effect in bringing Mexico, somewhat belatedly in comparison with a number of other, smaller developing nations, is something taking a lot of Raygoza's time. He is in constant contact with involved associates in Mexico. Getting off on the right foot is very critical.

Meanwhile, we have spent some common free time discussing lunar analog options, and in particular, what Jesus foresees as a possible future for the MexLunarHab project.

Jesus has already secured 200 hectares, 494 acres, 0.77 square mile in a plot some 200 kilometers SE of Ciudad Juarez (the growing industrial metropolis across the Rio Grande from El Paso, Texas.) The road to the site follows the south bank of the Rio Grande and the mountains on the Texas side dominate the view. As with the land across the river, this is very dry desert area. I've been along I-10 between El paso and Van Horn and in comparison, the deserts of New Mexico are lush oases.

His plan is to put up a mockup Lunar Lander and a nearby research station and a "recreational area" for robotic rover contests. Elsewhere on the site would be a domed greenhouse for biological research. A visitor center would be part of the project, and a major source of income for continuing research.

The Lunar Lander is reminiscent of the Zubrin design, except Raygoza's current sketch shows three floors (3 stacked tuna cans, if you will) with a different interior layout from the current Zubrin design as exemplified by the mockups on Devon island, in Utah, and the one being outfitted currently for Iceland. From bottom up:

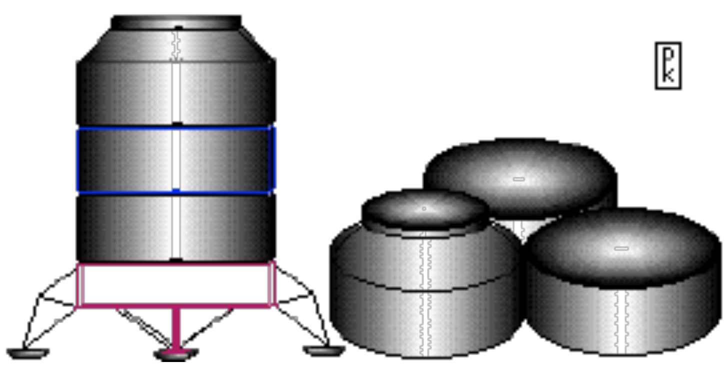
1st level: sleeping, leisure activities, kitchen, bath

2nd level: operations, communications, infirmary

3rd level: laboratory, workshop

This arrangement is, of course, a proposal that can be modified later as various considerations come into play. The stack would sit twice as tall as the Apollo LEM. The landing platforms are similar.

We discussed the possibility of the Lander being open to tourists, while duplicate "tuna-can" stacked but separable floors could be arranged side by side in a triangle on the desert floor -- an arrangement that would not only be shielding friendly, but eliminate the constant negotiation of ladders between levels, an open flirtationwith accidents and physical, muscular stress.



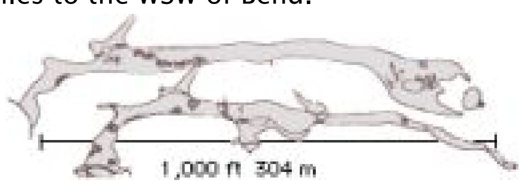
We have many more notes to compare. It is in our interest to have a number of Lunar Analog Research Stations, all trying different things. That way, we all stand to learn the most, and that bodes well for a future civilian lunar settlement effort.

Usefulness of Terrestrial Lavatubes in a Lunar Analog Research Station Program

By Peter Kokh

In August 1992, I had the wonderful experience of a personal guided tour of the pair of lava tube caves outside Bend, Oregon that the Oregon L5 Society was using for outpost simulation purposes. My guides were Bryce Walden and Cheryl Lynn York of Oregon L5.

Oregon Moonbase Photo taken during a simulation. The PVC tube frame would be covered with a tarp to serve as a makeshift base for students. The cave floor is flat due to the invasion of volcanic ash from the explosive eruption of Mt. Mazama 4,800 BC that formed the jewel known as Crater Lake, 85 miles to the WSW of Bend.



Above: Young's Cave complex outside Bend, Oregon

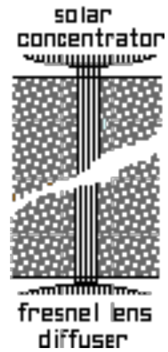
Lavatubes on Earth are much smaller in scale than those on the Moon, probably in some inverse relationship to gravity. The widest portion of the Young's Cave complex is 79 ft., the greatest ceiling clearance 26 ft. but these dimensions are uncommon. Because of their much smaller scale, they are hardly simulation stand-ins for those on the Moon. But we can put them to some use. And on July 20, 1989, NASA granted the Oregon chapter $25,000 to do a thorough site characterization.

The Geological survey was done by Stephen L. Gillett, a consulting geologist now in Carson City, Nevada with U-NV-Reno. Century West Engineering of Bend did the engineering analysis. A series of 5 borings, in roomy locations specified by Oregon L5, showed the roof to be generally from 10 to 20 feet thick with 7-19 ft of hard basalt overlain by 0-3 ft of loose soil. Except for a few transverse cooling cracks, the ceiling is relatively intact and rock quality analysis shows the roof could support from 2-60 tons suspended weight per linear foot, depending on varying roof thickness and the presence presence or absence of fractures. For this, a system of rock bolts will do. In weak areas, roof-shoring supports are advised. Some 6000-7500 cubic yards of sand forms a floor 0-6 ft thick. This could be removed, if desired, by vacuuming. Rock debris could also be removed, if desired, by backhoe or by hoists through openings made in the roof, thereafter available for installation of equipment. But creating such openings whether by blasting, jackhammer, or rocksaw would be a major undertaking. The variations of surface terrain was also surveyed.

The estimated cost of preparing the site as a major lunar analog facility as outlined by the Oregon Moonbase team was over $6 million 1990 dollars. The Phase II grant never came.

Eventually, the chapter decided to let the renewable 5-year lease on the facility expire. But on the basis of what we learned about this pair of lavatubes during the study, we think that this facility, if we could regain access, or a similar tube elsewhere, could support unique simulation exercises. If the main moonbase facility was up on the surface nearby and only limited simulations done in the lavatube, the cost could be significantly lower, with a very modest initial presence expanded on a pay-as-you-go basis.

The five 60 mm (2 3/8”) bore holes through the tube roof-ceiling could be used to drop in miniaturized survey equipment designed to demonstrate how we can robotically map the interior of lunar lava tubes, profiling their complex shapes and cross-sections. These tests finished, the bore holes could be filled with fiber optic bundles to let in sunlight concentrated up to thirty times. One bore hole could be used for communications access.



A small Habitat complex could be put together from small inflatable units or of EZ assemble-disassemble semi-prefab structures. At such a facility, where, within the lavatube, lighting would be totally controllable, we could more easily simulate the lunar dayspan/ nightspan cycle. We could examine ways of dealing with the two week long nightspan that would let a crew remain productive throughout. We would try to determine how little power we could get by on and still be productive, concentrating on repairs, maintenance, inventory, and other power-light, manpower-intensive tasks, so as to better use the 15 days of dayspan solar power available to store up power to tap after lunar sundown.

Meanwhile, a nearby surface conventional outpost complex would investigate and demonstrate other things: teleoperations; in situ resource utilization; shielding options; and many more lines of investigation. While it would be ideal for the companion analog surface outpost to be very close to the lavatube entrance, a separation of a few miles should not hinder operations. Crew would go from one to the other in a “pressurized vehicle.” This allows room for latitude if it is not possible to have both outpost components closely collocated.

As the access to the Bend, Oregon site can’t be recovered, we might do something similar at lavatube locations at Craters of the Moon National Park, ID; El Mapais National Monument, NM; or Snow Canyon State Park, UT. The advantage of Bend is that the lavatube complex there is well known and studied, and familiar to a number of Moon Society members. **<MMM>**

MMM #202 - FEBRUARY 2007

Antarctic South Pole Station’s Food Growth Chamber

prototype for a lunar analog station greenhouse

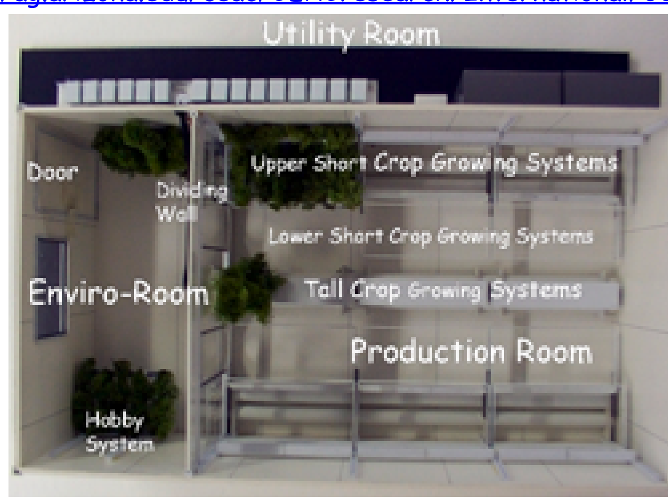
http://www.theepochtimes.com/ news/6-1-11/36815.html

It came out of the blue, as the silver lining of an ominous cloud: NASA's cancellation of all further research on advanced life support systems using plants rather than chemicals to maintain air and water quality both in the ISS and for the proposed lunar outpost. University of Arizona personnel working with private industry had come up with a working practical system. Demonstrated at the U.S. South Pole station, a rather modest 3 by 8.5 meter (10x28 ft.) facility, teleoperated at that, produces two salads a day for the post's 75 person crew. Meanwhile, it refreshes the air and water supplies.

Prototype for a lunar Food Growth Operation

While the facility is largely teleoperated, outpost personnel are on hand to intervene where necessary. The great thing about the system is its low demand on crew time, which is precious. That makes this system ideal for lunar and Martian outposts as well, and for ISS also. Yet no NASA money or supervision has been involved. "KISS" "Keep It Simple, Stupid" triumphs over pricey elaboration.

http://ag.arizona.edu/ceac/CEACresearch/International/004f.htm



http://ag.arizona.edu/ceac/CEACresearch/International/004f.htm

The sketch above shows that only part of the Food Growth Chamber is used for growing salad stuffs for the crew. An antechamber shown at left allows personnel to visit and enjoy the sight of lush vegetation. They can eat a meal here, and there is provision in this small space for crew members so inclined to grow their own herbs, spices, flowers, ornamental plants – whatever.

While the Food Growth Facility would have been successful without this antechamber, the latter has added to its popularity with the crew, boosting moral even further by enabling hobby time activities.

Costs and an Encore

This successful project, in operation for over two years, cost about $500,000 to set up – “half a Mil” – very modest by NASA standards. Its designers now want to create a second one, designed to fit inside a module that could be carried into space by a shuttle or in an equivalent payload bay or faring space. They have the Moon and Mars in mind!

In this setup, the Food Growth Chamber itself is separated from the rest of the post by an airlock. Inside the air is carbon dioxide enriched: plants thrive on this mixture. More, the light levels inside the chamber are high: not just reading level, but midsummer cloudless day sunlight level. This over-illumination contributes to the frequency base personnel pay a visit. Over-illumination is known to boost spirits and morale. Northerners used to cloudy winters can attest to the ill affects of overly long spells without the salutary brilliance of sunshine.

We are approaching the people involved in design and setup of this system in the hopes that one of them can make a presentation at ISDC 2007 in Dallas, May 23-28, Memorial Day Weekend. We’d also like to talk to them about how we could set up something similar, should we be able to setup our own Lunar Analog Research Station. One problem, which has thwarted Mars Society efforts to upgrade their modest MDRS GreenHab facility, is that personnel are on hand only part of the year. We’d have to involve local personnel during the off-season. But that the facility can be largely teleoperated would seem to reduce the need for on-hand involvement to a level it may be possible to arrange. Learning about this South Pole Food Growth Chamber certainly made my day. <**PK**>

MMM #207 - AUGUST 2007

M O D U L A R
B I O S P H E R I C S

“Tritreme Drain Plumbing” – By separating drainage by source type, each can be more efficiently treated.

By Peter Kokh

[Treme (Greek) = hole]

Cf. MMM #40 NOV ‘90, “**Cloacal vs. Tritreme Plumbing**”

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

Purging ourselves of the MIFSLA habit

The “MIx-First-Separate-LAter” (MIFSLA) attitude to waste water management” has gone virtually unquestioned since the invention of urban sewage systems in a city whose name we do not know, but whose ruins we refer to as Mohenjo-Daro, on the Indus River, about 200 miles NNE of modern Karachi, Pakistan, in 2,500 BC, four and a half thousand years ago. Another case of infra-structure being the most difficult thing to change, and thus the thing that deserves the most attention.

MIFSLA is so ingrained, it is taken for granted, almost never questioned, never thought of. “It’s just the way we have always done it.” How many times have you heard someone say that about something?

Waste Water treatment by Source Separation

www.holon.se/folke/projects/vatpark/Kth/guntha.shtml

On the Moon, where we are starting fresh, we have not only the ideal opportunity to do so, but an urgent imperative. Creating and maintaining a functional biosphere is daunting enough. Creating one that will keep operating as both the settlement and its biosphere keep growing ever larger.

> “The conventional waste water management system is unable to purify the sewage water to a higher grade than the nutrient content of the grey water. Biological plants are not well adapted to the purification of a mixed sewage, but if source separating toilets are used, the urine and feces could be used for agriculture, and the grey water could be efficiently purified with biological methods to a grade that it can be reused in the settlement.”
>
> Folke Gunther, Stockholm - URL above

Obviously, if we are going to build and grow settlement biospheres in modular fashion, with contributing components in each new habitation and activity module, we don’t need to make it more difficulty simply for the sake of “the easiest (most familiar) way.”

The MIFSLA Way of Doing (or not doing) **Business**

- Clean water is mixed with urine and feces to a polluting mixture, both regarding plant nutrients and pathogens.
- This mixture is in turn mixed with a fairly clean grey water (sinks, bathtubs, showers, laundry).
- The resulting mixture is diluted with drainage water (rain) (About 80 m3/person*year [19]) in an extensive web of piping.
- Finally, the mixture is expensively purified to a quality comparable with the original grey water, but with a doubled volume.

Folke Gunther, Stockholm - URL above

Wetlands-type systems accepting MIFSLA loads do not do as good a job, especially in reducing phosphorus content, as would be possible if the differing loads were treated separately.

Common Toilets mix wastes also

In the common water closet, urine and feces are water-flushed together. But there are several designs which separate most of the urine from the feces, so that both can be treated and recycled as agricultural fertilizers separately. There are several types of composting toilets designed for off-the-plumbing-grid use, and they function well, if instructions are followed.

At the Mars Desert Research Station, the original toilet was a composting one, operated poorly, with high odor problems. This may have been the result of improper installation, but more likely was the result of higher load (more users) than it was designed for.

We personally favor the Wolverton System, in which combined urine and feces are flushed into a tank inoculated with microbes to destroy the pathogens and break down solids, the effluent feeding a runoff planters producing clean fresh odor-free air, green foliage, under sunlit conditions. Such systems are load-restricted, but if used in every habitation or activity module in a number to match expected loads, would both turn the black water into gray water while contributing to the biosphere mass and function. This seems the best match for “Modular biospherics” that we have seen, however, improvements and alternatives are always welcome.

In our earlier article, written long before we heard of the Wolverton system, we suggested that toilet wastes be collected in changeable holding tanks. You would put a full one “out front” to be replaced with an empty one, by a municipal utility service. Utility personnel could make the switch in your home at an extra fee for convenience.

Separate drainage can be carried much further. Waste water from various types of industrial operations each have varying types of adulteration, each suitable for a special kind of treatment. Mixing industrial waste waters makes no sense and compounds the problems.

To insure proper installation and connections, drainage systems meant for different types of effluent could be color-coded. This is a system that we can make work. We need only the will to do it right.

Separate Gray Water Benefit

Pretreated odor-free gray waters irrigate “Living Walls” and can feed waterfalls, fish streams, fountains, and other delightful water features. The result would be a more pleasant settlement. <**MMM**>

MMM #208 - SEPTEMBER 2007

Society President takes part in Public Debut of Calgary Space Workers Mobile Modular Moonbase “Command Center”

By Peter Kokh

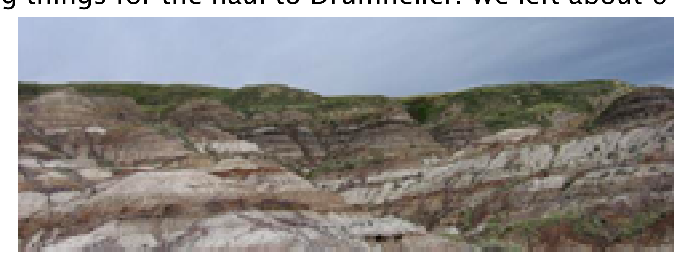
Ready for the move to Drumheller, Alberta Badlands site: The used 31 ft. Airstream Travel Center has been reoutfitting as a “moonbase command center.”

Calgary, Alberta, Thursday, August 23, 2007 – I arrived 11 A.M. MT on a Frontier Airlines Frequent Flyer ticket (15,000 miles) from Milwaukee via Denver and was met at customs by John Hadden, a member of the Calgary Space Workers Society. We recognized each other from pictures. After lunch at Wendy's not far from the airport, we went to John’s home, in NE Calgary, where he got ready for work (2nd shift) and I pecked at this keyboard before dozing off. The cooler Canadian weather was welcome.

In early evening, long time friends Paul and Holly Swift, who used to live in Toronto (Paul chaired ISDC 1994) and who have been in Calgary for ten years, picked me up and we went out for ice cream. Paul is head of the Calgary Space Frontier Society chapter.

Friday, August 25, 2007

We drove to Michael Bakk’s home on the south side, and it was easy to tell when we were there, the truck trailer combo pictured above was parked right in front. Mike is head of the Calgary Space Workers Society. The two groups work together closely. We did some more work on the trailer, securing things for the haul to Drumheller. We left about 6 pm for that location.



We arrived just before dark, secured the truck and trailer beside the Homestead Museum where events were to take place on Saturday, found a hotel and got a bite to eat. Alberta east of Calgary is mostly treeless plains with few trees. Drumheller sits in the Red Deer River valley, long known as Dinosaur Valley for all the fossils found there. It is quite the tourist mecca. They have had an unusual amount of rain this year, and the valley was much greener than usual, not exactly what we wanted for a moonbase setting. The soft eroded contours of the hills do remind one of the soft meteorite-eroded contours of the lunar terrain.

The next morning we got everything set up and were ready for a stream of visitors who never came. As luck would have it, a local lad was one of four remaining "Canadian Idol" contestants, and he was in town to thrill locals and visitors with his singing.

Sunday, however, we had fair traffic. I took notes to give Mike on how to improve his setup, displays, and handout materials, and brainstormed how he could set up an analog moonbase operation despite all the vegetation.

Rationales for a Mobile Modular Outpost Architecture

This Calgary group is pursuing a mobile modular approach and that makes a lot of sense. While the Mars Society is trying to cram all outpost functions in one structure, NASA expects to deploy several interconnected modules on the Moon, an architecture that is modular could be made friendly to further expansion, if done right. While NASA's outpost will not be mobile, a mobile one would serve the needs of explorers who wanted to visit several sites, provided that these sites could be easily reached overland. The crew could just "break camp" and tow everything to a new location and set up shop there.

No one analog site serves all needs

But there is a practical down-home reason for mobility. There are many things an "Analog" Lunar Research Station" could explore and test. Geological field work and and equipment would require a pretty good mineralogical and geological similarity of the analog site to conditions on the Moon. But on the one hand, NASA has already done this kind of research on the Moon itself during the Apollo years, and on the other, there are few really good analog sites on Earth for this purpose. As to processing technologies, these can be tested in a lab. Biological field work is also inapplicable. The Moon hosts no life, not even the most primitive.

Physical Regolith analogs

Regolith handling, on the other hand, is a whole complex area of activities in which we are unsure of ourselves and of how to proceed. And here we are dealing with the physical behavior of the regolith particles, their mineralogical makeup being irrelevant. Where will we find terrestrial material that behaves like regolith? It is very unlikely that we will. We may have to make it. And since we will need lots of it, hundreds of tons if not much more, we need to find the cheapest combination of ingredients that will do the trick. We talked about this in MMM #200, November 2006, p 10. Analog Outpost Options Cont: **Physical Analogs**

If we focus on regolith handling technologies, teleoperations, and other research areas where the geological and mineralogical character of the site is not relevant, then we can set up shop wherever it is convenient for logistical or other reasons, importing our special surface material to the site.

Drumheller's Dinosaur Valley

East of Calgary, broad flat sedimentary plains stretch for hundreds of miles through the Canadian breadbasket of Eastern Alberta, Saskatchewan and SW Manitoba all the way to Winnipeg. The Red Deer River flows from the Canadian Rockies through this plain, its course taking it between Edmonton and Calgary toward Drumheller, where it has cut a deep valley. In the sides of this valley, many a dinosaur skeleton has been found.

The Calgary Space Workers: Why Drumheller?

The Calgary Space Workers found this site somewhat moonlike, and it is. Not unlike similar sedimentary eroded hills and cliffs in south central Utah around the Mars Desert Research Station, Dinosaur Valley too has soft rounded contours, the work of soft and hard rains through the millennia. If you are old enough to remember the artistic portrayals of the

Moon's mountains by Chesley Bonestel and others, you may remember our surprise on arriving there, that there were no sharp craggy peaks and crater rims, but mostly soft rounded hills. Even the mountain size hills (Apollo 15's Mt. Hadley is some 15,000 ft or 4,500 meters give or take) looks like just a taller round hill. In the Moon's case, it was not a watery rain, but the incessant soft micrometeorite rain which has smoothed most edges. Lunar slopes are seldom more than 30° while those at Drumheller and Hanksville can be somewhat steeper, up to 50°.

That, however, is where the similarity ends. You can clearly tell the different strata revealed by the carving waters in layers of sedimentary rock, just as you can in Utah. Only here, the colors are more subdued, more gray. In that respect, Dinosaur Valley is more apt than Utah.

Utah wins in that it is more arid, the rains coming much less often, and in the area around the Mars Desert Research Station, there is almost no vegetation at all. In Drumheller, however, there is quite a bit of inconvenient greenery, especially at the time of my visit – this season has been one of the wettest on record for Drumheller. On the average, the valley gets only 32.5 cm (12.8 inches – compared to 5-9 " in Hanksville) and very little humidity.

Finding a site:

Will the CSW crew be able to find a site where this inconvenient green distraction is minimal? On our visit, Michael Bakk, CSW "Captain" spoke to several landowners who were receptive to the idea of hosting his facility. We will see what the future will bring. Expense is an issue, and a donated site will have to do.

Dealing with vegetation:

Having and maintaining a Moon-like atmosphere, here in a psychological sense, is much more important for productive effective work by the crews that visit the site, than one might think. The rounded gray hills, themselves fairly denuded, certainly set the scene. It is the vegetation on the valley floor that is the problem.

One way to deal with it would be a 6-12 ft tall mound row or wood fence, painted to blend in with the hills above. That would block out eye level vegetation beyond. But what about vegetation within the perimeter? One could uproot it and install barrier fabric that would discourage new growth. Using herbicides should be a last resort. One would want to return the site to its natural state in due time. Above the fabric, one could deploy the imported physical analog regolith material.

Many things affect the expense of such an approach such as size of the area within the perimeter. For the purpose of teleoperations experiments, and regolith handling experiments, and shielding experi-ments, a few acres should do, but of course, the more, the better. This is an approach, however, that allows expansion.

Adding Lunar "Regolith"

Perhaps most our moonlike brew could come from the various sedimentary rock layers in the surroun-ding valley walls. There are coal sediments nearby that could be powdered to "blacken" the mix. Available also are sandstone (silicates) and bentonite, an aluminosilicate weathered from volcanic ash. Finely crushed glass and powdered iron would add to the physical behavioral similarities we want. For the finest element, talcum powder might work, but Canada is an importer, not an exporter of this product. Perhaps a local second best product could be identified. One thing is important: to avoid materials that plants find fertile!

While NASA's outpost will not be mobile, a mobile one would serve the needs of explorers who wanted to visit several sites, provided that these sites could be easily reached overland. The crew could just "break camp" and tow everything to a new location and set up there.

No one analog site serves all needs

But there is a practical down-home reason for mobility. There are many things an Analog Lunar Research Station could explore and test. Geological field work and equipment would require a pretty good mineralogical and geological similarity of the analog site to conditions on the Moon. But NASA has already done this kind of research on the Moon itself during the Apollo years,.

It all began with an Airstream

Michael Bakk had identified an available used Airstream Travel Trailer as as good a starter module as any. It was streamlined, aluminum clad, and mobile. This module demonstrates utility systems, air recycling, hydroponics and other control and command systems. Next in line is a Workshop that would allow expansion work and alterations and hookups to be done on location. The workshop may be a hard hull module also, rescued from some prior use.

Next would come an inflatable connector tube into which all the major modules would be plugged. I'd suggest that crew quarters (a dorm) should come next, because only then will visitors be able to imagine themselves as part of a crew on the Moon. An agricultural – biosphere–biowaste recycling system is also planned. And from there, the options are endless.

Money, money, and more moneyN

Of course, such an ambitious plan can hardly be realized by clipping coupons, selling lemonade, or by washing cars. To their credit, CSW has already raised over $50,000 in donations. That is a very respectable sum for a relatively small local outfit. They seem to know what they are doing, be aware of the cards stacked against them and determined that they can put it all together.

The Moon Society cheers them on, and will help in whatever non–monetary way we can. While we work on our own plans and also look for a suitable location, the footwork of our friends in Calgary, will make our path and choices easier. Go CSW, go! **<PK>**

Not Previously Published

What a Lunar Analog Research Station Should Attempt to Demonstrate

By Peter Kokh and Moon Society Advisor David A. Dunlop

May, 2006

First let's clear the ground by pointing out that the goals of a Mars Analog Research Station are not necessarily the same as those of a Lunar counterpart, and vice versa.

For Mars advocates, the goal to be defended, the feasibility to be demonstrated, is that humans and robots together can explore Mars much more effectively and thoroughly than robots alone.

Mars advocates are trying to get the nation (and, hopefully, international partners) to commit to the manned exploration of Mars. Settlement, while a dream of most, is a goal well over the horizon.

In contrast, Lunar Advocates are operating with a given national commitment to a "permanent" manned outpost on the Moon, whatever "permanent" means.

We have many times pointed out that any outpost remains tentative until there is a permanent civilian population on the Moon raising its own successors, and supporting its own domestic needs as well as earning credits towards imports by products and services based on local, i.e. lunar resources.

We have already had humans on the Moon exploring limited areas.
Manned exploration is not something whose feasibility we still need to demonstrate. Thus our goals go beyond those of Mars advocates.

- We do not need to demonstrate the methods and tools of human–robotic exploration,

- We do need to determine which operations can be done effectively by teleoperation from Earth in order to dedicate precious man-hours on location for those things that can not be done as well by teleoperation
- We do need to demonstrate the methods and tools of expansion of an outpost into a settlement.
- We do need to demonstrate the options for using local lunar resources to accomplish that goal.

Demonstrating Maximum Use of Teleoperations

Our long term goal is to ensure the creation of a viable lunar frontier where people of many walks of life can work, play, and raise families, supporting themselves by the production of export goods and services. To the point, there is one thing in common with all "new frontiers" in the early stages of establishment.

There is always more work to be done, than people to do it.

Our best opportunity to make sure that precious man-hours are most economically spent is to identify and demonstrate operations that can be effectively performed by personnel on Earth, "teleoperating" at far lower costs per hour. The Moon has the advantage of being only one and a fraction light-seconds from Earth, a manageable time delay.

Site preparation (grading, leveling, removal of boulders, trenching, etc.) and shielding emplacement are two obvious areas where teleoperators working on Earth should be able to get the job done, leaving crews on the Moon for other things, not so easily "farmed out." But we need to determine the best equipment to be sent to the Moon for teleoperators to control with under 3 seconds time delay.

What other operations can be so farmed out? Here lies a whole world of things that can be tested at a lunar analog station. Every operation that can be done remotely, extends the productivity of those on location that much more. Advance scout rovers could be teleoperated; mining equipment, manufacturing equipment, agricultural tasks, perhaps even road construction. Let's find out!

Demonstrating Dayspan/Nightspan Power Generation

An outpost needs power, of course, but NASA is not currently committed to demonstrating a system to store power for use during Nightspan. Instead, the agency seems committed to demonstrating that the need to do so is unnecessary, because the outpost will be at the South Pole, where allegedly sunlight is available all the time.

If we are going to bring the whole lunar globe into the realm of a Greater Earth-Moon Economy, we have to be able to set up shop wherever resources and other assets demand that we do so, not just at one of the poles. And that means demonstrating a Dayspan/Nightspan power system. Indeed, we should demonstrate several systems, not only for backup, but so that the technology can pick the winners.

The options are several. A small nuclear power plant is, however, something totally out of reach financially for a privately supported Lunar Analog Station here on Earth. But that doesn't really matter, because outposts and settlements will come in all sizes, while "nukes" may come only in one size, and at high expense, a non versatile solution.

Hydrogen/Oxygen Systems: Fuel Cells

Excess Dayspan solar power could be used to electrolyze graywater and water in reserves into hydrogen and oxygen which can be recombined in a fuel cell to produce both power and potable water. Fuel cells could also be fed by hydrogen scavenged from solar wind volatiles by heating regolith soil being moved in the process of road construction, materials processing, site grading and excavation, and import of regolith into pressurized farm areas for use as soil. Fresh oxygen can be extracted from the regolith by several well understood and demonstrated processes. Harvesting hydrogen and extracting oxygen would be day-span activities.

Hydrogen/Silicon Systems: Silane-fueled Generators, Vehicles, and Appliances

Another entirely different possibility should be explored. Carbon is scarce on the Moon, much more so than hydrogen. Thus methane is not a fuel option. But Silane, SiH4, a silicon analog of carbon-based methane, may be.

Silane could be called a "hydrogen extender," in as much as silicon, being much more common on the Moon than hydrogen, is used to stretch the total power output of a given amount of hydrogen. Silane has been proposed as a lunar appropriate rocket fuel.

I had some time ago asked Dr. Robert Zubrin if the adiabatic process (occurring without loss or gain of heat) to be used in making methane from the Martian atmosphere could be applied to production of Silane on the Moon. He answered in the affirmative. That leaves us with the belief that this is a direction worth pursuing.

- First we could demonstrate methods of producing Silane from regolith. Engineering competitions at the College- University level are an option worth pursuing.
- Then, by similar competitions, we could seek to demonstrate Silane-fueled generators, Silane-fueled vehicles, and Silane-fueled appliances.

The Silane would be produced during Dayspan in quantities sufficient to fuel appliances and vehicles at all times, and generators during Nightspan. Silane-fueled generators could also be used at all times at small construction camps and other temporary installations where it makes no sense to deploy a large scale solar (or nuke) power system.

Continuing productivity through the Nightspan by "change of pace" task sequencing

Few things need demonstration as much as the ability of pioneers to survive the two week long lunar night. Here on Earth, alternating fortnights of full daylight and total darkness (except for Earthlight and starlight) within a warehouse or arena with blacked out windows and total lighting control. But we can come close at an outdoor Habitation structure such as the Mars desert Research Station, by having the crew active for two weeks during local daylight hours, then shift to a schedule offset by 12 hours, awake and active only during the local Utah night. The portholes and windows could be blacked out, or uncovered, as needed to create the right atmosphere inside. Crews would go outside only during daylight, and nighttime hours alternately over a four week cycle.

We might learn more from week 1 Dayspan, weeks 2 and 3 Nightspan, week 4 Dayspan. That way two transitions, from abundant power to rationed power, and from rationed power back to abundant power could be modeled. If we could only afford to rent the MDRS facility for two weeks, we could operate on a 4 day light, 7 day dark, 3 day light schedule, telescoping the lunar cycle into half the time.

In such a light/darkness regime, crew members could experiment with the management of operation tasks to suit the greater amount of power available during the two "daylight" weeks, and the lesser amount available during the two "nighttime" weeks. Various tasks could be separated or precipitated out into energy-intensive ones to be executed during the light period and energy-light and perhaps labor-intensive tasks to be taken care of during the night period. Some operations will lend themselves to such a sequential execution, others may not. It will be a learning experience.

Meanwhile, we can demonstrate power generation during the Dayspan period by use of photovoltaics, and solar concentrators, and other means. During this period, excess available energy would be used to electrolyze graywater, as suggested above. For backup to fuel cells, we could develop and improve Silane-fueled generators, furnaces, ranges, refrigerators, and rovers.

For more on the topic of Dayspan-Nightspan task sequencing, confer these back articles:

MMM #7 July, 1987 "Powerco" – reprinted in MMM Classics #1

MMM #43,March,1991 "Dayspan," "Nightspan" – reprinted in MMM Classics #5

MMM Classics Pdf files are freely downloadable atr:

www.moonsociety.org/publications/mmm_classics/

Modeling "Modular Biospherics"

1. Modules for expansion

Expansion of our outpost(s) is(are) can not reasonably be supported by the prohibitively expensive import of habitat modules and connectors manufactured on Earth. With so astronomically expensive a cost per square foot of usable space, the governing constraint will be to jam pack each unit with equipment, reducing crew quarters and recreation space to "sardine can" cubbyholes, and making many desirable activities much too expensive to support.

The next step would be to bring in inflatable structures packed uninflated and compacted for the ride to the Moon in constraining payload bays and farings, then finish outfitting them on location. These could be spheres, cylinders, or torus-shaped volumes. The latter provides a stable "no-roll" level footprint and the greatest volume to height ratio, making shielding easier. While inflatables designed for use in low Earth orbit must have foot-thick membranes to protect against puncture from orbital debris, inflatables designed to be covered with shielding on the Moon would need only a much thinner membrane, meaning that inflated, they could provide significantly more volume (with perhaps ten times the membrane surface area) than similar LEO-destined inflatables, when both are to be transported in the same size payload bay or faring. The real challenge of inflatables is to design interior systems that can be quickly and easily deployed, once the structure is inflated. Again, college level design competitions may prove useful in coming up with elegant solutions.

The real breakthrough, however, will be the achievement of the capacity to manufacture modules and module components locally on the Moon with made-on-Luna building materials: metal alloys, glass fiber reinforced concrete, glass-glass composites. The price of new space will be reduced drastically. The outpost will grow module by module, along with the crew - the population.

2. Making each module of the growing structure, also a module of the growing biosphere

Meanwhile, we will have to grow the biosphere that supports the complex. The simplest and most elegant way to do this is to equip every lived-in, worked-in, played-in, learned-in module with a Wolverton* type toilet system that flushes sideways through the bathroom wall to water a row of platers beginning with water plants, swamp plants, marsh plants, bog plants and then soil plants. By the time the black water leaves the module, it is 95% pretreated, vastly reducing central water recycling system loads.

To learn more about the Wolverton System, check out:

http://www.wolvertonenvironmental.com/

These "principles of modular Biospherics" are something worth modeling and demonstrating at a Lunar Analog Research Station. Such a system will go well beyond whatever system NASA uses to refresh air and water in a fixed size outpost, and thus demonstrate the technologies needed for expansion of an outpost into a real settlement.

The modules would need to pipe in sunlight or alternately, banks of grow lamps. (The pathways provided for sunlight could be used by light from intensely bright external sulfur lamps during Nightspan.) The plants within each module would largely refresh air within, and fill the interior with the greens of vegetation and the color of flowers: fresh air, greenery, color - not an add-on but an integrally designed feature of each module.

In such a system, the biosphere grows one module at a time. The settlement's physical plant does not outgrow the biosphere's capacity because the two are one and the same. Not just the major modules that comprise living, working, and recreation space, but also the connecting passageways and "streets" should do their share by hosting plant rows along their sides. We must always keep in mind that

it is not a case of humans playing host to house plants, but of vegetation playing host to humans, enabling our survival!

We could build our Analog Station with a mix of hard hull modules, inflatable modules, and modules made of materials we should be able to process on the Moon. Perhaps the core operations would be in the hard hull starter units:

1. Crew Quarters – Library – "Quiet Spaces Module"
2. Workstations: communications, controls, monitors, reports, teleoperations, CapCom, Office
3. Kitchen, Pantry, Ward room, meeting space
4. Bathroom, showers, exercise & fitness area, First Aid
5. Lab space for work on geological and mineral samples
6. Utilities: power, thermal control, engineering workbench
7. Airlock and suit-up area. Dust decontamination

The above modules could be directly interconnected or connected via passageways, as the needs for isolation or of juxtaposition dictates. This basic 7-unit complex contrasts with the all-in-one approach illustrated by FMARS and MDRS. The Lunar Analog Station, by beginning as a modular complex, would be set to grow in like fashion. Additional modules could be added for recreation and sports, arts & crafts space, and areas for experiments with processing and materials. The complex would begin to look like a self-sufficient commune.

All units would house vegetation. This would be in addition to the Greenhouse, itself modular, which could grow as success, food demand, and the desire for more variety increases. A Greenhouse area could host a picnic corner, a get away reading spot, a biocrafts area, and so on.

Thus a Lunar Analog Station would not be a weak "me too" operation, but one with rather ambitious goals that go well beyond what the Mars Society is attempting to do. It is only fair to point out, however, that The Mars Foundation is moving in that direction also. This group is attempting to identify all the technologies needed to transition an outpost into a permanent settlement on Mars, and dreams of building a prototype Mars settlement somewhere on Earth.

Other things worth demonstrating at a Lunar Analog Research Station

- Teleoperable shielding emplacement systems
- Erection of shielded hangers within which to indirectly shield pressurized modules and/or to house supplies and systems that need to be accessed on a regular basis
- Greenhouse systems
- Early industries: cast basalt, glass, fiberglass, glass composite, concrete, metal alloys
- Art media using only lunar producible materials
- Refurnish the Habitat with objects made in the above demonstrations. And on and on

Evolution of the Analog Complex with regular "Updating Makeovers" as new technologies are demonstrated

Of necessity, the initial complex modules will be built with available terrestrial materials. However, right from the outset, floors could be finished with cast basalt tiles made in Czechoslovakia and marketed in the US out of West Virginia. We could also start out with interior walls constructed not of 2"x4" wood studs and drywall (as is the case at MDRS and FMARS), but of steel studs and duroc™ cement board. Not only would that be closer to what we might end up doing on the Moon, it would be a fireproof

As we demonstrate new materials technologies, we could then replace more and more of the original materials, furniture and furnishings used in the station with those analogous to what we might be able to produce on the Moon. In this manner, the quality of the "simulation" would keep increasing – proof that we are learning things worthwhile!

A Lunar Analog Station as a Part of a larger Project

A Lunar Analog Research Station is but one part of a grander dream of the Moon Society, called Project LETO {Lunar Exploration and Tourist Organization] which would involve a major tourist and educational center. It is my opinion that the research facility should not be included in such a complex but located separately in an appropriate isolated landscape. However, a twin facility at the tourist center, evolving (expanding and upgrading) in step, would be available for regular tours. It would have monitors at each location to show web cam views of what is currently going on in the real research station.

The Mars Society relies on publicity for its analog stations to increase public support and funding. But a sister complex open to tours with a peep hole into the actual one, if located in a high tourist traffic area such as Las Vegas or Orlando, would greatly increase public exposure, public enthusiasm, and, equally if not as important, a steady flow of donations and new members.

We can do some of these things suggested above at the Mars Desert Research Station in the 2007 Field Season - for example, a first modeling of operations through a complete lunar dayspan/nightspan cycle.

However, the demonstration of a modular bio-spherics expansion architecture, as it involves the facilities themselves, would necessitate an independent operation on a separate site. It would be foolish to make major capital investments in a facility not our own, and from which we planned to move. Further, there is no reason to believe that the Mars Society would approve any such expansion plans. If we want to do these things, we must find another site and deploy a fresh habitat complex of a friendlier design.

As for a new site for our new modular complex, locating it in a "lava sheet, lava tube area" would be optimum for silane and/or fuel cell based utilities, cast basalt operations and other materials processing and manufacturing operations we want to demonstrate. It will take some time both to identify a new site and acquire access and use.

It would take more time, and money, to deploy our desired complex. However, we could start with a mockup complex of rented or purchased used old camping trailers, replacing them one at a time with new construction. This is a plan that would involve the minimum interruption in annual simulation exercises, a plan that would maintain momentum.

We can do this! But not without donations! and major sponsorships from companies who stand to benefit from developing the technologies needed. **PK/DD**

Directions of Lunar Analog Research

By Peter Kokh

There are already a good number of lunar analog research programs around the world. But we have to stop thinking in terms of Mars Society type facilities. First, there is plenty of research that begs attention for which a "movie set" location is not relevant. Second, the potential sponsors are not only space advocacy organizations such as the Mars Society, the Moon Society, or National Space Society. There are a number of University Departments that are very much engaged. Even some aerospace contractors engage in analog exercises.

Possible Types of Lunar Analog Research

- **Modeling Outpost Architectures**
  NASA has created a number of test bed mockup moon base modules, some hard-hull, some inflatable. This type of actual modeling identifies architectural problems and challenges and leads the to solutions
- **Biological Life Support Experiments**
  NASA had its Bioplex, and had previously supported a number of other experiments. Work had also been done at the University of Purdue. Currently creative research is underway at the University of Arizona's Controlled Environment Agricultural Center - CEAC. And not to be dismissed is research and experimentation that may be applicable underway by various "back to nature" groups.

• **Experimental Lunar Agriculture**
This is not quite the same as biological life support but is surely interrelated. We need to supply crops that not only will provide sufficient and well-balanced nutrition, but something as important for mental health and morale as nutrition is for physical health: a repertoire of plants that can be prepared in many ways to provide a diet that is as interesting as it is healthy.

Experiments with robotic and teleoperated systems, freeing the crew for other things; and integration of agriculture into the air and water refreshenning process, as well as into the ambiance of crew living spaces in general.

Adaptation to the lunar Dayspan/Nightspan cycle is also important. More energy will be available for plant growth during dayspan than nightspan. Experiments that pin-down the optimum lower-energy diet for various kinds of plants during nightspan are critical. For this kind of research, we need an environment that is visually sealed off from the outside world, for simulation of the lunar dayspan/nightspan cycle. This can be an underground facility or any windowless volume.

• **Modeling lunar site preparation methods**
We need to develop equipment and teleoperations methods so that a moon base site can be prepared in advance for the first crews. This type of research needs a "sandbox" environment to play in. Such sites may include "movie set" locations where the geology, landforms, and coloration is superficially analogous to what we might find on the Moon, or Mars as the case may be. But for teleoperated site preparation experiments, all that is really necessary is a big enough "sand box" in which the "sand" has been worked to serve as a physical analog of moon dust, i.e. behaving physically in the same way. Its chemical or mineralogical makeup is irrelevant. What is relevant is the mix of particles of various sizes – the mixture's "workability."

• **Power Generation and Power Storage Systems**
These kind of experiments do not need any special kind of environment.

• **Determination for each area of operations which energy-intensive tasks can be reserved for dayspan and which energy-light tasks can be reserved for nightspan so as to calculate overall nightspan power needs** – this can be done anywhere, but an environment In which lighting can simulate the lunar dayspan nightspan cycle would set the mood.

• **Experimental production of building/manufacturing materials from lunar simulant** can be done anywhere

The MDRS experience is not relevant

A Mars Desert Research Station type facility is useful for testing geological tools and methodologies and for other areas of experimentation requiring a large "sandbox." At MDRS, exobiological or astrobiological "prospecting" is also a frequent activity, but this does not seem to have any parallel for lunar research. While the location does put one in the spirit of being on Mars, and does simulate (most imperfectly) the isolation of being on Mars (help is only 15 minutes away, a few hours at most), it is not needed for agricultural and related biosystems experiments, nor for human factors studies.

Indeed many analog research options are ignored in the MDRS operation. The impression that there is nothing else to model, however, is quite off the mark. As for modeling habitat architecture options, this has been precluded by the up front decision not to expand the Mars Hab or to reconfigure it in any way. The opportunity to test new power and utility systems is taken only when necessary, as when a system that fails to frequently is replaced. No effort has been made to rely on methane, producible on Mars, as the sole power source.

A Decentralized Plan will work

A comprehensive lunar analog research program could consist of many sites:

• **A movie-set analog landscape "sandbox" site**
testing site preparation equipment
testing teleoperations technologies
testing rovers and other mobile equipment

- **A Visitors center** – this could be near the sandbox site and use webcams and a “duck blind” trail for viewing crew activities without distracting the crew. But a visitors center could also be built at a “lunar landscape” location such as Craters of the Moon National Park, or near a high traffic space-interest site such as Spaceport America. Together with a motel, they could both be ongoing experiments in modular lunar architecture, and furnished accordingly. If there were other lunar analog research nearby or adjacent that would be great but not necessary.
- **Modular Architecture and Modular Biosphere**. We could model such systems at a “movie-set” location or at a Visitors Center or both. Expansions could test new solutions, and encourage revisits as either complex continues to grow. Adding a Moon Motel could be part of the plan, increasing opportunities to experiment. Not only would the architecture use simulated lunar materials, but the interior finish and furnishings as well
- **Agricultural Research has no special site needs**
- **In Situ lunar materials research** can be near sources of needed materials, or just anywhere. Proximity to other analog research activities might draw more attention, but is unnecessary

A Decentralized Plan for the Moon Society

- **No special sequence need be followed, other than convenience and opportunity**
- **We can cosponsor work already ongoing**, perhaps funding a special extension thereof. There may be an opportunity to do this with already ongoing biospheric and agricultural experiments.
- **We can cosponsor research ongoing or proposed at various universities.** This could cover many kinds of research.
- **We can open our own Visitors Center and expand it as funds allow** as an example of what we can do on the Moon
- **We could fund carefully designed chapter projects** that fit our guidelines on lunar analog research options

Each opportunity has to be analyzed for initial and continuing funding needs, personnel and staffing needs, equipment needs, site preparation or alteration needs, etc.

Modeling An Expanding Lunar Outpost

By Peter Kokh – October 31, 2009

Our Design Philosophy and the Research Opportunities that flow from it: Modular and Shielded – Year around operations

Our design philosophy is of a soil-covered “shielded” modular station, connected by enclosed walkways linked to a central Command and Communications hub. The site chosen should be one that allows this initial complex to grow in modular fashion as additional new research directions are pursued.

This “shielding,” while necessary on the Moon (and Mars) to protect from the cosmic elements (cosmic rays, solar flares, micrometeorites), also protects the outpost from thermal extremes. While only this last benefit will be relevant for our analog stations here on Earth, it will serve to even out seasonal temperature highs and lows and thus allow year-around occupation. That in turn will allow significant biological life-support experimentation and greenhouse agriculture to supply fresh vegetables and fruit to the crews.

Adopting a modular approach suggests that some experimentation with modular architectural languages and construction methodologies is itself a research direction. In turn, an expansion-friendly modular architectural plan provides the opportunity to model biological life support systems on a modular plan. Every hab or lab module, even every connector could include living biomass so that as the physical complex grows, so does the life-supporting biosphere. In pursuit of thus line of research, a plurality of toilets offers the opportunity to experiment with a plurality of black and gray water systems, Modular connecting corridors, if wide-enough, could not only provide wall-space for a surplus of storage lockers but wall space for a variety of living wall systems, again experimenting with a variety of such systems to learn which works best and in which respect. Again in turn, this environmental research is bound to spin-off technologies useful here on Earth, winning us overdue appreciation and support from the environmental community.

Carrying the green theme further, that the complex, being soil-shielded, will be operational year around, allows the inclusion of a greenhouse operation to supply fresh vegetables, and in time fresh fruit as well, to an uninterrupted succession of crews. Learning from the experience of Biosphere II, any type of agriculture system totally dependent on human labor, may result in everyone working overtime just to produce a starvation diet. We need to automate greenhouse systems, and, as a back up, rely on teleoperation from off-site individuals: a great opportunity to involve students, as well as a great opportunity to experiment with different automated and teleoperated equipment.

[NOTE: at the time of this writing, 10-31-2009, the idea was to have one analog research site at which all of these research directions could be pursued. We no longer see that as necessary or the best uses of scarce funds and personnel time.]

Research Opportunities that flow from the Simulated Outpost Structure

- **Modular Architecture Systems:** Connecting hallways**, Modular** utility systems, Ergonomics, Versatility
- **Modular Biospherics:** Graywater systems & Toilets, Living Wall systems, Tri-treme plumbing systems
- **Agriculture:** Robotic and teleoperated systems - teleoperation invites students and others to participate

Research Opportunities that may flow from an Analog Environment

The Sandbox - teleoperation experiments

Desert-type sites offer a “sandbox” to play in, as do some quarries. That suggests that one research focus might be testing robotic and teleoperated earth (regolith) moving equipment to be used in site preparation (grading, leveling, removal of boulders, trenching), shielding emplacement, road construction, and mining operations. We could test equipment for soil sortation and sifting, sandbag filling equipment, block/brick production, etc. Placing soil shielding over the original complex, and over new modules as they are added, provides an ideal opportunity for experimentation, and will probably result in evolving engineering designs of the equipment involved.

On the Moon, a less than 3-second time delay is something that simple experiments show can be easily mastered. But how far can such teleoperation take us? Some activities will require quick responses that may set a limit on the practicality of teleoperation.

Volcanic deposits - basalt products

If the site is volcanic/basaltic in nature, that would be especially helpful. The lunar maria or seas are really frozen seas of lava, the surface layer of which has been pulverized into basalt-rich moondust (regolith). On the Moon, the ease and simplicity of using basalt as a material indicates that hewn, carved, and cast basalt will be one of the earliest lunar industries. Experiments along this line could develop commercial products, which could earn supporting income for the complex. Currently, the Czech Republic produces cast basalt tiles of unique beauty, strength and abrasion resistance. Solid basalt could be quarried from road cuts through lava sheet flow fronts, to make construction blocks as well as blocks for sculptors. In India, basalt fibers have characteristics superior to glass fibers and even carbon fibers. How practical basalt-based research would be at any particular location is uncertain, but we raise the possibility.

Abandoned mine galleries above the water table

Some mining areas may offer galleries above the local water table. That would be ideal “pre-shielded” volumes in which lighting, read simulated 29.5r Earth day long dayspan/ nightspan cycles can be simulated.

However, the lunar dayspan/nightspan cycle can be simulated in any structure shut-off from outdoor daylight.

This opens four major research opportunities:

1) Passive Thermal Management Systems

Storing Nightspan cold for Dayspan cooling - There are working systems on Earth which store excess summer heat for winter heating and excess winter cold for summer cooling. While the temperature difference on the Moon is much greater, so is the length of our heating and cooling seasons. The total degree-days in each case are likely to be significantly closer. Development of such systems would mean much lower nightspan power demands for heating purposes.

2) Demonstrate dayspan/nightspan operations to minimize power storage needs.

(Continuing productivity through the nightspan by use of "change of pace" task sequencing - This would be simplest to do in subsurface voids such as handy lavatubes, caves, or mine galleries. But there is a way to do it in shielded surface facilities. The goal is to determine the optimum power demand ratio between dayspan and nightspan operations.)

a) Energy intensive (and manpower light) tasks during dayspan

b) Manpower intensive (and energy light tasks during nightspan.

The goal is to see to what extent various typical outpost operations can be sequenced to go with power availability

3) Demonstrate nightspan power storage systems

- Fuel cells producible with lunar elements (Platinum-free?)
- Flywheels
- Closed loop hydroelectric systems (using a nearby elevation gradient)
- Other systems? Hybrid systems?

4) Experimental Lunar Agriculture

Plants are used to a 24-hour day/night cycle. That these mine galleries and naturally in darkness all the time, allows us to experiment with growing plants on a lunar dayspan/nightspan schedule. Two weeks out of every four, they can be given all the light they can handle. The question is, that to minimize nightspan power demands, how little light can we give them and on what kind of schedule, so that they eventually go on to harvest. The “Nightspan Dark-hardiness Experiment” is likely to give different results for different plants, even for differing varieties of the same plants.

Conclusion

The above architecture-related and site-related research opportunities do not exhaust the possibilities. But they provide a rational for logical future expansion of any initial research program for a lunar analog research station or family of research centers.

With each of these opportunities, comes a parallel set of options for student outreach. Any Moon Society Lunar Analog Research facility should be designed and located for an open-ended future for both research and educational opportunities. ###

Artemis Society’s Project LETO Proposal
Visitors Center &/or Research Station

http://www.moonsociety.org/projects/leto/

[This Project has been in Limbo since 2004]

From Greggory R. Bennett, founder, The Moon Society

[L.E.T.O. = Lunar Exploration & Tourist Organization]

“Project Leto is the first major long term project for the Moon Society. It is a strategic plan to build a full-scale simulation of an initial lunar exploration base. It would be marketed for outreach purposes, analog research, and as a tourist destination.

"We have been in the process of assembling a business plan and soliciting funding for the project. The initial site would likely be located in Las Vegas (to capitalize on the large tourist industry) As it matures, Project Leto would encompass activities at many sites, including locations in Hesperia, California and Hawaii. Other candidate locations being considered include Oregon, Idaho, Arizona, Florida, and New Mexico.

"One option is to construct a pair of identical analog research stations, one for tourists to visit in Las Vegas, and another in a remote location with terrain analogous to what we will find on the Moon. This second station would then be where the real research is done. But visitors to the twin station at the tourist center would be able to listen in, and watch by webcams."

http://www.moonsociety.org/projects/#other

From Peter Kokh, succeeding Greg Bennett as President

"As a proposal to combine a tourist center with research station activities, Project LETO presupposes that these two different types of activity are compatible. Every indication is that tourist activity would shatter the concentration of research station crews, there being ample anecdotal evidence from the Mars Society's experiences at the Mars Desert Research Station in Utah. But a mockup station at the visitors center, where the pubic can watch activities at a remote research station via live web cams, might be the better solution. Such a solution would make it unnecessary to make compromises either as to the location of the tourist center or as to the geologically appropriate location of the research station. Further, under this plan, the research station could have web cam access to a multiplicity of research stations scattered around the globe.

"The Project LETO plan also begs the question of which should come first: a tourist center to bring in money and new members, or a research station. There can be no question about the paramount importance of both.

As to which should come first, perhaps the best answer is both, with tourist center and research station both being built in phases, growing in parallel, however closely or remotely collocated.

Our priority is to define and design exactly the kind of Analog Research Station that we need to pursue our goals of research, development, and demonstration,

find an appropriate site, with hard choices being made with due consideration to land cost and logistics of construction and support.

Then we can take up the idea of visitors centers, and yes, why not more than one. If the connection is made via web-cams, an inexpensive visitors mockup moonbase could be replicated in several tourist traffic nodes or wherever donor-sponsors wanted to place them.

"Because money is an object, and Project Leto as conceived would cost an order of magnitude larger capitalization, our focus is on continuing to refine our design for a phase by phase realization of an initial lunar Analog station. See a presentation on the current state of this work-in-progress brainstorming effort. **PDF file** Slide Show.

http://www.moonsociety.org/moonbasesim/proposals/AnalogMoonbaseProposal.pdf

June 1989 NASA JSC mock-up of Space Station Freedom:

One of the many things that can be improved upon by modeling exercises is “modular construction itself.” The Space Station did not turn out to look anything like the above, but this full call model would make a great lunar analog station, if it were still available, which is most unlikely.

Not all lunar analog research requires a lunar analog landscape or terrain. In fact, most of it does not. Modeling modularity could be done in connection with a visitors center, an accompanying motel or both. Compatible research would include modeling lunar interiors using materials that could be produced on the early frontier: concrete, some metals, carved, cast, and hewn basalt, etc.

Another important area of research, which would be totally compatible with a modular station, is the concept of modular biospherics. Indeed, it be a wasted opportunity to attempt to model one without the other.

If a greenhouse is added to supply the crews with fresh vegetables (and, eventually fruit) then we could also test teleoperable plant cultivation equipment to free crew members for other things.

As the process of testing modular architectures and compatible biosphere systems will not keep crew busy, other lines of experimentation could be added:

- **time-delay teleoperation** of construction and other equipment in a “sandbox” area
- **testing shielding emplacement techniques**
- **adding new modules (construction)**
- **testing rover and other moblle mockups** with new features and systems

The opportunities are wide open, and will depend in part on the location/ landscape. ###

The Role of Design Contests and Engineering

Lunar Analog Research must extend to Transportation Systems Needed to deploy an Outpost, and Expand it

By Peter Kokh

In MMM #238 September 2010, we talked about getting past the Peenemunde V-2 guided missile mindset that only the “warhead” is the payload. Rocketry “realists” are wont to remind us that the mass fraction rule means that only a small fraction of the total launch mass can be payload. We pointed out the hidden and unnecessary and indefensible assumption that everything but the designated payload is wasted.

No! No! No! If we want to open the space frontier we must get the V2 mentality behind us.

The truth is that **"If it's not fuel, it's payload!"**

We have the whole of the NASA and Contractor culture to reeducate. Rather than try to do so, however, it may be productive to concentrate on the younger generation who will take over in time. We can do this by running annual design and engineering competitions for the best ideas on how to design farings, spent fuel tanks and engines, and spent stages in the "transformer" mode, that is to serve some other function and use once their original transportation task was completed.

Young people have grown up with Transformer™ cartoons and toys. They will understand the concept. They can make the leap in imagination whereas those brought up in the V2 mindset cannot begin to imagine what we are talking about.

Look at the landing platform and legs and see a mobile traveling crane! Look at spent descent engines and imagine a lunar hopper transport. You get the idea.

Culturally, this fits the slow evolution away from one use throwaway design towards a recycling system made easier because everything is designed of components easy to separate and reuse for new purposes.

"Recycling comes to Rocketdom!." But it is only fiction if we allow it to stay that way. Today's fiction can be tomorrow's reality, if we make it so!

Actually, there is a proud, if unsuccessful tradition in the space enthusiast community of just such an effort, to find post-launch uses for Space Shuttle External Tanks in orbit.

Must Reading:

Report on Space Shuttle External Tank Applications
By J. Alex Gimarc (**Paperback** - 1985)
2 used from $29.99 (Amazon.com

We even convinced Congress to order NASA to take ETs to orbit if a company was ready to reuse it. The law should have required NASA to put ETs in a high altitude storage orbit, for eventual reuse. NASA dodged the bullet, but not to their credit. There will come a time when this waste is recognized for what it has been: a crime against the future.

If you want to help us design such contests and competitions, please contact us at:

contests@moonsociety.org

The Bright Minds of Young People Can Advance Lunar Analog Research In many ways, and in many areas

Some Suggestions

Module Interior Design and Outfitting

Students input, through design competitions, could help design module interiors: sleeping quarters; wardroom and commons areas; command and communications centers, exercise centers, and so on, choosing among two contest formats:

1) given module size and shape constraints

2) free design on the assumption that the module size and shape will be chosen to fit the desired outfitting.

Mission Control/CapCom

● Students could man "Mission Control/CapCom" operations. When a non-routine incident comes up they could defer to an expert remote team with special experience

Publicity - Communications - Press Releases

● Students could man an off-site (or on-location) radio and or TV operation to keep the outside world up to date on what's going on at the station. Note: Station designation **KMBE** - "**Moon**

Base Earth" is available

● Students could write up crew reports to post on blogs read by other students worldwide.

Teleoperations

Students could teleoperate cultivation and other tasks in a Greenhouse, and maintain the greenhouse in any off-season periods in which crews are not present.

Art forms

Students could use art forms that are practical on the Moon with materials and ingredients that could be produced on the Moon, to create wall art and sculptures and other forms to adorn the station interior and exterior surroundings – pathways, for example.

Summary

In the Mars Society operations on Devon Island and in Utah, the student resource is underutilized. True, you have to make distinctions between student levels. But at all levels from Middle School through High School, through undergraduate and graduate College and University levels, there are young people able and willing to commit free time to do many useful things.

And after all, young people are our future. Why wait until they are adults to offer them ways to get involved? It is important to remember that by adulthood, unfortunately, many brains and imaginations have started to set in ways that discourage free thinking. Why has it taken us 70 years to get out of the V-2 mentality that the warhead Is the payload, when potentially everything that is not fuel is payload? Adults too quickly decide that "we can't" simply because "we haven't yet." Young people can help us transcend these mental blocks in the way of a fuller future.

All Moon Society analog research projects and programs should be analyzed for opportunities to involve students constructively and creatively at all levels. **PK**

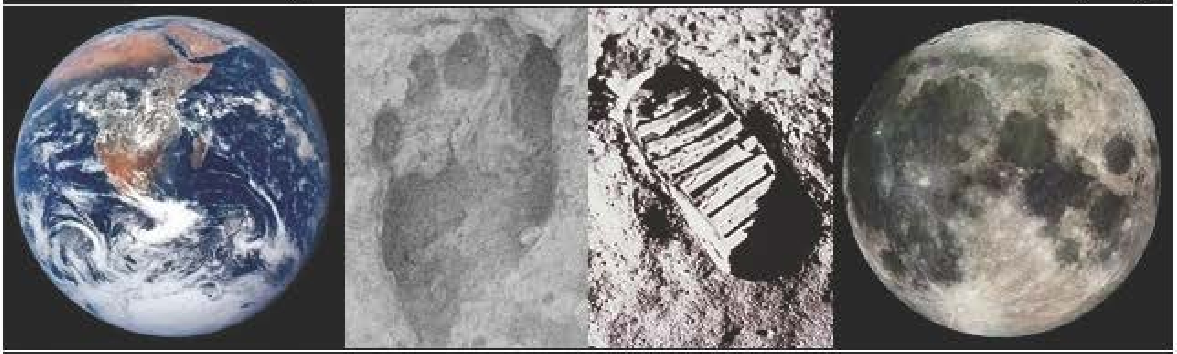
A Selection of our Analog Concept Illustrations

http://www.moonsociety.org/moonbasesim/proposals/AnalogMooonbaseProposal.ppt

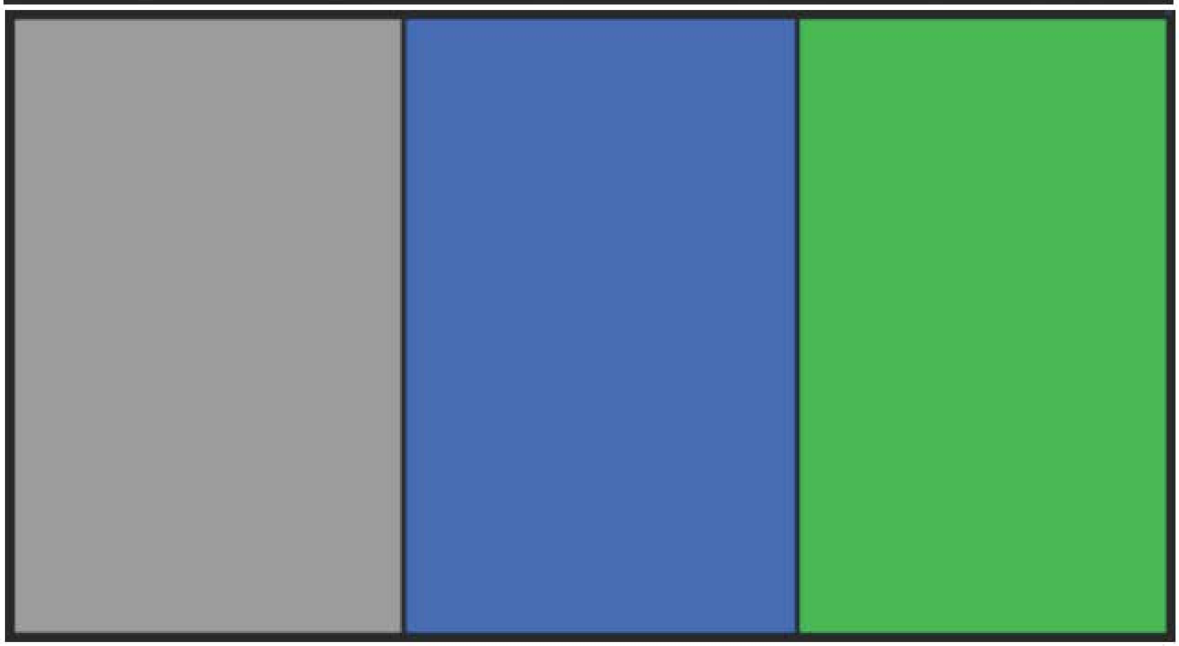
"If you are going to dream, dream big!"

The Moon Society

The Moon Society - Lunar Frontier Settlement - www.moonsociety.org



From Africa to the Moon, the Human Epic told in footprints, continues to the stars!



LUNAR ANALOG RESEARCH PROJECT

PLAQUE TO BE DISPLAYED AT ALL MOON SOCIETY SPONSORED OR CO-SPONSORED LUNAR ANALOG RESEARCH PROJECTS

In 2006, the Moon Society adopted a Flag to fly over the Mars Desert Research Station in Utah during its 2-week long **Artemis Moonbase Sim 1** exercise, as **Crew 45 - February 26 - March 11, 2006**. In advance, crew members were asked their preferences on a set of possible flag designs. There was no consensus at all, so the crew commander, Pete Kokh, deferred to the pattern set by the Mars Society flag that always flew over M.D.R.S., the "Red Mars, Green Mars, Blue Mars" Tricolor. For the purposes of this simulation exercise, we had a flag made in the Tricolor motif. Our Colors were, left to right, Gray (for moon dust), Blue (for water), Green (for vegetation and biosphere). -- This is an Analog Research Projects flag, not a proposed Moon Flag.