"Expanding the Human Economy through Off-Planet Resources"

Moon Miners' Manifesto

& Moon Society Journal

MMM Classics

Year 16: MMM #s151-160

December 2001 - November 2002

This year we continued sketching what it will take to allow pioneers to begin to feel "at home" on the Moon. One thing is clear, we will need spacesuits that are not so cumbersome and movement constraining. L>M>R at top we see an original Apollo Moonwalker suit and two very different solution prototypes, the "moonskin" counterpressure suit being the most interesting.

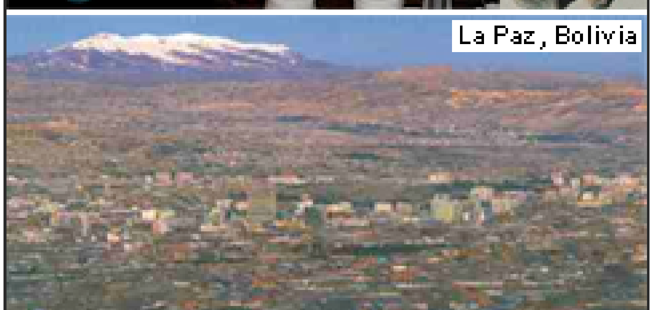
We also sketched how our moon homes themselves could be "at home" in this alien environment.

In "To Mars by way of La Paz: (Bolivia), we pointed out that over 1,500,000 persons now lived at nearly 13,000 ft where air pressure is just over half that at sea level. Now on Mars, nitrogen is relatively abundant.

But we followed with an article that points out that the supply of Nitrogen, not Carbon or Hydrogen, is the pinch point for lunar settlement.

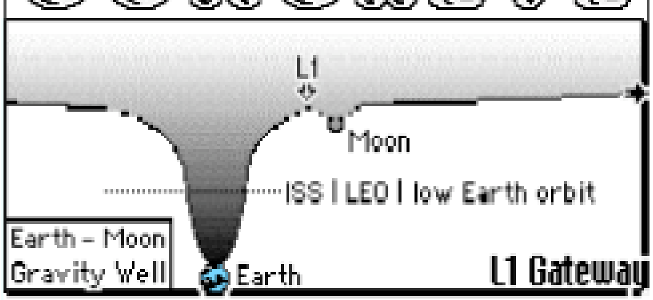
By simply reducing the partial pressure of nitrogen, the same tonnage of nitrogen will let us provide 2.73 times as much pressurized volume. We attempt to shatter all the myths about "normal" air pressure, including the myth that NASA determined that 1 ATM is preferable.

Again on the theme of atmosphere, we wrote about the role of "atmosphere mining" on Mars to provide feedstocks for a non-petrochemical organic materials industry on Mars.



79 k N_2 21 k O_2 = 79% N_2 21% O_2 **1.0 ATM**	29 k N_2 21 k O_2 = 58 % N_2 42 % O_2 **0.5 ATM**	**2.72 times** as much volume with **same Oxygen** **partial** **pressure**

CONCRETE



This year featured two articles on the role of concrete, which could well become the workhorse construction/building material on the Moon, just as it has long been here on Earth, where this material has been undergoing round after round of reinvention. "It's not just for pavement anymore." Concrete has received far more attention, research & development, as an *in situ* (geek for "on location") lunar resource, than any other material (glass, metal alloys.)

With NASA's announcement that it wanted to move beyond ISS and low Earth orbit activity to build another space station at the Earth-Moon L1 Lagrange point, on the grounds that it would serve as a forward staging point for operations on either the Moon or Mars (to be decided), we looked into this idea. On the face of it, the idea seemed absurd, much like building O'Hare airport before founding Chicago.

Yet no one can deny that Earth-Moon L1 is a strategic location with clear advantages. Our reasoned counterproposal is to develop an L1 gateway in a "just in time" and "as traffic warrants" phase by phase approach. Space facilities in Earth orbit have limited life-times, as systems decay and or are damaged. It makes sense to add facilities to L1 only as the need for them becomes clearly imminent. *Enjoy this volume!*

MMM #151 - DEC 2001

Learning to be "at Home" on the Moon

We began our "at Home" discussion last month, and continue it this issue and for a few more to come. Actually, this has been *the central theme* of MMM since issue #1, fifteen years ago. We chose the word *"Manifesto"* as an indication that MMM would be *a bold, brash, defense of an unlikely position:* we *can* be at home on the Moon and elsewhere. =>> *below*.

Engaging the Surface with Moonsuits instead of Spacesuits

"Mother Nature has a Dress Code!"

by Peter Kokh

In last month's issue (MMM #150 NOV '01) we began our discussion of learning how to be "at home" on the Moon with articles on domesticating regolith, getting comfortable with overnighting, and learning to live with the Moon's natural rhythms. But there is much more to this agenda, and we pick up the litany this month. First on the list: lunar space suits!

Space Suits have traditionally been designed *to protect* us from alien environments, not *to engage those environments* on a *"let's make ourselves at home"* basis. These would seem to be just empty and cheap words at first reaction, but let's play with the idea, follow it, and see if it leads *somewhere new*.

When NASA sent astronauts to the Moon, it was with suits designed to protect them from a poorly understood and understandably "alien" environment. They did have a good understanding of the thermal loads and heat-management problem, of the radiation flux at the Moon's surface, and some inkling of the uncooperative character of the pervasive moondust. In designing the suits, it was essential to err on the side of overprotection. After all, the scientific goals of these missions were definitely secondary to the overriding directive to "bring 'em back alive!"

When we return to the Moon, the controlling directive will be *to learn how to stay*. Breaking the systems engineering and psychological barriers of overnighting will be at the top of the list of milestones in this campaign. And that will mean that we must have suits that can do more than handle the moderate "midmorning" solar heating loads. They must be up to handling the higher heat loads of "high noon" and of the lunar "afternoon" period (remember that from sun up to sun down takes a full 14 and three quarter standard Earth days). But in order to do outside routine and emergency housekeeping, maintenance, and other chores during the equally long sub-bitter cold nightspans, the suits must have a controllable heating capacity with high reliability. Proper insulation against heat loss by radiation to the black sky will be essential. So even without the extra features we will identify as desirable below, the suits for the return missions will have to be improved, at least in thermal management capacity, over those of the Apollo era.

So much for the obvious.

What we want to talk about in this article is the need for Moon Suits that go beyond such improved basics. We need to put to work the tremendous electronic telesensing abilities that have become doable in the three decades since the Apollo feats.

Smart Suits

For safety' sake and to maximize the odds of safe return, or rescue if that should ever be necessary, we can build a number of sensors and computer processor chips into our new "smart" moonsuits. The wearer should have at his or her demand, all of the following kinds of vital information:

- power reserves and time available at current energy consumption rates
- oxygen reserves and time remaining at current consumption rates
- thermal management stress loads as a function of capacity
- radiation flux with screen becoming activated when flux exceeds normal range
- built-in GPS (global positioning system)
  - □ distance covered (GPS track)
  - □ over the horizon landmark locator (GPS calculator)
  - □ direct return route distance (GPS calculator)
- warning when the capacity of any system approaches the "point of no return" level

The readouts from these devices could be either constantly visible, or projected on the visor "heads up" area either when activated by a voice command or automatically when a caution or emergency condition develops. No one needs to be unnecessarily distracted by boring confirmations that everything is "functioning within normal parameters," but information that requires attention, must have a way to get attention. An alternative to a heads up display for less critical information would be a sleeve readout device.

A transponder belongs in every moonsuit. It could broadcast its signals via satellite or via a relay at one of the Lagrange point station (L1, L2, L4, L5 -- according to one's location on the Moon's surface). To personnel at the outpost or vehicle from which the suited excursion originated, the wearer's position would be monitored (as a backup system in addition to the suit's own GPS monitor.) If there was sign of inactivity lasting long enough to cause concern, or a cut off in transmission, or a signal that a suit function had failed or been compromised (e.g. even slow depressurization from suit puncture), the wearer's location would be pinpointed.

Additionally, if someone sensed s/he was in trouble, the whereabouts of any nearby persons also out on the surface could be ascertained, and a route to their location plotted or a signal sent.

One of the tradeoffs of such safety features is that if the Big Brother aspect. There are times when one may want to be alone -- just him/herself, the moonscapes, and his/her thoughts. One should be able to turnoff a transponder, but with a double switch to prevent accidental disconnects.

These kinds of :"Guardian Angel" features are well within current technology limits. They would make us *more safely* "at home" on the Moon. There is more we can do, so stay tuned.

Smart Visors

Not only can we thus greatly improve moonsuit safety features as described above, we also have it within our power to greatly enhance the wearer's perception of his/her environment. In comparison to the "Native Scout" expert clue recognition abilities that moonsuit wearers will "put on" when they don their suits, the Apollo moonwalkers had all the clue-less sensory capacity of city slicker dudes. No offense intended, of course! They were all genuine heroes of the first rank who did all they could and more with the tools we gave them.

Our point is that it is not enough just to be able to look through a helmet visor with the naked eye. Moonscape's are notoriously monochromatic and the immense information that they bear comes across to the naked eye as a monotonous blur of seemingly trivial details. Smart Visors and other electronic sensory enhancers could change all that, and allow the wearer to see an immense variety of significant information of scientific, prospecting, or other value that normally fades into the monochrome overload.

Smart Visors and other sensory enhancers will allow future moonwalkers to "engage" the Moon as never before, by letting them see and sense information clues that "naked eyesight" just can't detect, notice, or pick out. Here are just some of the possibilities that are within our means.

- infrared scanning of the ink black shadows and knee-mount shadow penetrating spotlights
- phosphorescence sensors
- picking other humans out of the background
- exaggeration of slight and subtle color difference
- telescopic zoom-in capacity
- sensors that sniff any outgassing in the area
- range finder (distance to near horizon features can be greatly misjudged by the naked eye according to Apollo EVA experience)
- level horizon guide (in low gravity, one's ability to detect slight slopes is impaired)
- filters that enhance visibility through any dust electrostatically suspended over the surface
- alert-alarm and activation of laser spotlights when sensors in combination with expert recognition systems detect the special spectral and reflectivity signatures of minerals etc. on a field science or prospecting watch list
- alert alarms for any motion in the visual field
- alert alarms for any motion in the shadows
- other expert recognition programs
- major computing power to analyze inputs (the computer design should address the clumsy gloved fingers vs. keypad issue using voice recognition software and other means, be able to calculate mineral and element abundances of samples, and, using GPS and range-finding data draw simple but functional "map" guides)

We've probably missed a lot of other possibilities and if readers have some suggestions to add to this list they are encouraged to contact MMM by mail or by email <KokhMMM@aol.com> But the list above will give some indication of the enormous potential there is to use today's electronic wizardry to let future moonwalkers be vastly more attune with and aware of their environment. "Engaging the Moon on its own terms" is what we are after -- the ability to be able to see critical information normally lost in the visual monotony as if one were an experienced native-born scout.

Wearability and Mobility Issues

Comfort and Convenience were justifiably secondary concerns fro the designers and fabricators of the Apollo moonsuits. One can put up with most anything on a temporary basis, so long as the discomfort or inconvenience is not great enough to compromise the work at hand. But now we are going back to the Moon, intending to stay, intending to make ourselves at home. Field scientists (geologists, mineralogists, etc.) and prospectors and others will be out on the surface for longer periods, and repeatedly. In such circumstances, discomfort and inconvenience risks compromising the work at hand.

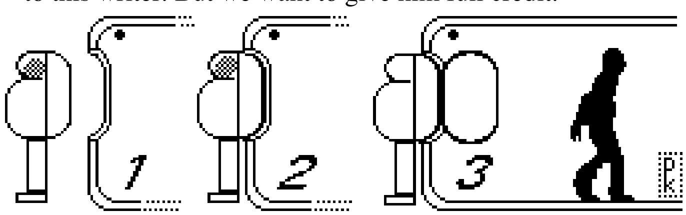
What do we need here? Surely suits that are easy to put on and easy to take off without assistance. And suits that do not require pre-breathing special air mixtures. We need to make it so wearing proper apparel to go outside on the Moon is no more of a big deal than wearing proper apparel for rain, cold, wind, or snow is for us on Earth. In short we need suits that protect us without a lot of bother and drama.

We shouldn't attempt to find an ideal design that offers such features in isolation from the even more important issue of dust control. The use of conventional airlocks will inexorably lead to the in-migration of annoying and trouble making amounts of fine powdery moondust into pressurized habitats, labs, workspaces, and other facilities. Previously we have proposed a solution prefigured in illustrations by the great lunar outpost illustrator, Pat Rawlings -- the clamshell-back or turtle-back spacesuit. We described its operation in the MMM #89 article cited at the bottom of this article.:

> "Pat Rawlings who did the illustrations Ben Bova's 1989 book "Welcome to Moonbase" [Ballantine Books, New York, ISBN 0-345-32859-0] has elsewhere illustrated a much superior dust-control approach. The cover of "Lunar Bases and Space Activities of the 21st Century" [W.W. Mendell, Editor; Lunar and Planetary Institute, Houston 1985, ISBN 0-942862-02-3] shows personnel wearing what I have come to call the "Turtleback" suit, in which an oval hardshell back-

pack covers the torso and back of helmet. This backpack is hinged on one side, and entry to the suit is made through the opening.

"In prerelease 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 word) 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."



Next we need suits which are as light as they can be made, and agile! There are probably things we can do with both the boots and the loves to make the wearer more sure-footed in all types of lunar terrain, and more dexterous in handling samples,climbing, making repairs or performing service operations. If our moonsuits constrict our mobility and agility, making us "all feet and all thumbs," wearing them will exhaust us all too quickly, decreasing both the amount and the quality of work accomplished.

The amount of quality work that gets done per person hour is the name of the game. In time, it will also be a question of enabling people to go out on the surface to engage in field hobbies and out-vac individual or team sports. If we meet the needs of the scientists and prospectors, we will enable those with an "outdoors" recreational needs as well.

Out-vac exercise and sports activity of any kind will depend on the invention and debugging of a lightweight, supple pressure suit that can handle the heat and perspiration loads generated. If total out-vac exposure times are kept to an acceptable accumulative minimum, radiation protection can be minimized. Given the considerable benefit and boost to overall settler morale, the development of such a suit is sure to be on the collective front burner. Such suits will have to have many "smart" features we have described above.

For both work and recreation, overall morale enhancement is the real prize. Upon this morale hangs the long term viability of lunar settlement.

Now unlike providing sensory enhancement, providing EZ-wear suits that allow maximum mobility, agility, and dexterity is a goal much more easily described than realized. Our intent is not to give clues as *how* we can meet these goals, but to define *what* these goals should be. NASA has long been aware of the shortcomings of its spacesuits and for a time was funding two different teams to come up with replacement designs. Then the work stopped. There may have been some Agency dissatisfaction with the results being achieved in the two projects underway. Each was promising advantages, but by means that were mutually incompatible so that all the proposed advantages could apparently not be realized in either design. But we think that the real reason for shelving these two projects was Neanderthal budget-cutting, by those who could not see the big picture, or cared.

This kind of R&D needs to be directed by a commercial enterprise that has a stake in the results and in the quality and quantity of work done on the Moon. For now, brainstorming and paper studies of radical new moonsuit designs that meet these objectives are about all we can hope to see -- until some intently for-profit consortium has a eureka-dream that "there's (a) gold(mine) in those (gray) hills!"

Active Helper Systems

One could also imagineer a number of "helper systems" that would enhance the surface excursion experience even further. Power tool plug-ins Set II. In addition to tools useful in investigating rocks and minerals (drills, saws, core samplers, etc.) and various glove and boot accessories, we could "plug in" more exotic, even "handier" tools. How about an automatic laser device that would leave "Reeses Pieces" "hot spots" that would remain detectable for a few hours to assist the wearer in retracing steps especially in jumbled and confusing terrain?

Or how about a retrievable tethered mini "scamperer" probe that could reach spots (up/down cliffs and escarpments, inside crevices and clefts, etc. and other hard or inconvenient to reach areas) and either analyze what it detected and send back the data or pick up and return promising samples? The second season team at the Mars Society simulation outpost on Devon island discovered the surprising usefulness of such critters. They experimented with 100 m and 200 m tethers (leashes, anyone?)

We'd be delighted to hear from readers about more such active helper systems. Think of them as productivity maximizers and safety insurers.

The Fremen Stillsuits of Dune/Arakis

Okay, so that's a bad title in as much as those who do not allow the pleasures and escapes of science fiction into their lives will have no clue of what it means. To Sci-Fi fans, no explanation is needed. So let's try again.

Accommodating Human "Needs"

Our suits of the Apollo moonwalkers had provision for urination -- a definite improvement over the one Alan Shepherd wore less than a decade earlier. But these suits were made to enable stays of a few hours at most. We'll want to do some trial and error experimentation with alternatives that will cover our butts, so to speak, for longer periods under both normal and distressed conditions (er when it's Immodium time). Accommodating for regular bowel function (other than by the "low residue diets" fed to the Apollo crews) within the tight confines of a space suit will pose quite a challenge, but one we must meet sooner or later, so why not sooner?

Truly long-duration suits would have the capacity to recycle urine into drinking water, and for the uninitiated, that was the gist of the first subtitle for this section. Now that will make many queasy but it is no more than a very accelerated version of what happens in nature. So if this makes you ill at ease, get with the program!

Suits will have controls to adjust the gas composition of the air, and scrubbers to remove or recycle exhaled carbon dioxide. To create a "micro" biosphere system to handle all this indefinitely without frequent fresh inputs would seem an impossible challenge. Fortunately, some people relish "impossible" challenges. We predict breakthroughs in this area -- in time, and not by an "agency."

The ultimate backup system would be a "non-invasive" vital signs telemetry system. That is a nearer term goal, one we should find easier to meet.

Wrap Up - "Moonskin"

Actually, we are all born with a space suit of sorts -- our skin, which is one of the most important yet least appreciated of the body's essential systems. The skin works to keep our body fluids in and contaminants out. But this natural integument evolved to meet the challenges of our terrestrial environment. Now as we move out into spaces and places beyond our native atmosphere, we do not have the time to let "evolution" do its work in spinning us an improved form-fitting protection layer.

But the way the skin works without encumbering us to assist our mobility, agility and dexterity is the model we must hold before us in designing our "moonskins" the suits that will let us be at home on the Moon as if we were natives.

With the right outerwear, we could operate freely on the Moon's surface and be attentive of all the clues the moonscapes hold. Well designed moonsuits well let us "belong" in our adopted homeworld.

Relevant articles from MMM issues past:

#89 OCT '95, p.5 "Dust Control"
§ "Engineering Countermeasures - Suit-Locks"
#96 JUN '96 p. 6 "Spacesuit Aversion" <MMM>

Could we be "at Home" on the Moon without Pets & Wildlife?

by Peter Kokh

In today's busy, high-paced over structured society, many homes are without pets. More and more people have grown up without them, and have an acquired indifference to animals, if not fear. Perhaps because of increasing exposure to environmental pollutants, a growing percentage of the population is now allergic to many things, pet fur included.

Put in historical perspective, this situation is a sad aberration. Humans have lived with animals from prehistoric times. Cats have been domesticated for six thousand years. Dogs have been a standard part of human households for over a hundred thousand years. *In that light,* it is clear that *as a species, we have become "human" in the presence of dogs.*

The value of pets to the development of individual personality is well-documented. The benefits for children and the elderly are even greater. Yet many previews of life on the space frontier, perhaps the forecasts of pet-deprived and animal-insensitive individuals, would make no place for pets. But for those of us who have had the good fortune to have our humanity more fully realized by pets, it is clear that *as a fully human society* we will never be "at home" on the Moon or anywhere else with "just plants".

Pets may not produce tangible benefits. But what they contribute to morale and to humanity, however intangible, is too immense to be written out of the picture -- even if a fraction of our population has grown aberrantly insensitive and immune.

Recently, I was interviewed by a local newspaper reporter who asked if I would go to the Moon "to live" if I was offered the chance. I replied, "in a heart beat, provided I could take along at least one of my three dogs." Not all of you will feel the same. But if only the pet-insensitive are picked to go, the settlement that will result will only be a caricature of a truly human town, by all standards throughout time and in every corner of the globe.

And there will be a place for urban wildlife as well: hummingbirds, songbirds, bees, butterflies, fish and much more. Animal lovers still rule. <MMM>

[For those of you of "other traditions," read on. You may get some ideas on how to celebrate those as well.]

How to Celebrate The HOLIDAYS on the Moon

by Peter Kokh

Okay, so we made the final cut and we'll be shipping out to the Moon next fall. Right now, as exited as we are, Christmas is vying for our immediate attention. There's the tree to get. We wonder if for one last time we should leave the old artificial tree in the box in the attic and go get a fresh cut one. Then, this being our last Christmas on Earth, we want to buy some special gifts for those who have been dear to us and whom we may never get to see again.

Then it hits us. How are we pioneers going to celebrate the Holidays on the Moon? Oh, of course, there's no problem with the religious observances, or with caroling. And that's reassuring because these traditions are something we will always be able to cherish. But what about the material trappings of the Holidays? We enjoy them too! They've been part of our life ever since Grandma and Grandpa woke us up in the middle of the night with sleigh bells to let us know that Santa had been here. Face it, we treasure both aspects of Christmas.

We've become so thoroughly spoiled

If you are like us, you may have gotten used to artificial Christmas trees -- much cheaper over the long run, and you can leave them up as long as you enjoy them. And then there is tinsel, glass ornaments (We've always hated the plastic ones), foil garlands, and electric lights. (Oh how we miss the brighter, much more vividly colored large lights of the past! One consolation of being "older" is having those memories!)

And the boxes and gift wrap and ribbons -- most of it used once to be thrown away. Sure, there are some who save every scrap for next year. But they are the exception that proves the rule.

And the immense quantity and variety of things to buy and to give! Sometimes it is all a bit overwhelming. So much to choose from! For many of us, of course, the amount we can afford to spend acts as a brake and narrows the choices. But still!

But on the Moon ...

None of all that next year. On the Moon there won't be any Wal-Mart or Toys-Я-Us or Circuit City. Nor will the governing Council let anyone order anything out of a catalog, or even online. Actually, they don't have to police such restrictions. Our wallet will do that for us. Even lightweight items will be quite *expensive* to ship up from Earth.

So how are we to decorate? What choices have we for gift-giving? How are we to get in the mood without all the customary props? Are we going to be forced by the realities of the gravity well barrier to concentrate solely on the religious observances? Did we sign up for the Moon to become monks with marital privileges? Or will we find other ways to surround ourselves with some fitting trappings?

Answering my own Question

It is a wise man who said "if you don't know the answer, it is because you haven't asked the right question." "Will we be able to find other ways ..." Well there it is. Of course! It just takes the right attitude.

Once upon a time ...

We have always been able to celebrate the Christmas holidays with material items that put us in the mood of excitement and anticipation -- anticipation not just of receiving, but of seeing the delight in the eyes of those we give to (at least respectfully feigned) when they open the gifts we've gotten (or made) for them. Yes the Christmas carols and songs and music excite us as well. Yes, we're uplifted by the spiritual message of the observances. These are things that cost little money except when we insist on embellishing them.

But we've always been able to decorate, and to give, long before everything we have come to take for granted in the past century. Money may help, but it has never been a necessity. We will be pioneers. It is only fitting that we learn from pioneers of earlier times. If we pay attention to the *function* of decoration and to the function of gift-giving. letting go of familiar *forms,* we may find some clues, some ways to make next Christmas as good as any, if not better! *Attitude is everything!*

What do we have to work with?

Well, we have iron (steel by next year), glass, ceramics, cast basalt and ... You get the idea. No plastics or other synthetics. No quality alloys. No this, no that. But let's not sing along in that litany.

Those with artistic talents are encouraged to turn out accessories and other items that could serve as gifts in their spare time. Given that the factories are all busy producing items with export potential or necessary items for domestic lunar consumption, after hours arts and crafts are experiencing something of a special renaissance in the settlements. Guess we'll all be trying to cultivate our hidden artistic talents, such as they are!

According to the orientation classes that all settler recruits must take, we'll all be encouraged to participate in greater or lesser ways in the agricultural food-production and biosphere maintenance units. And soon, word has it, they'll start churning out built-on-Luna habitat modules to start giving us all some badly needed elbow room. What a boost for everyone's morale that will be!

Families will be in line to get their own home units, to become their very own "legally" once they have lived in them for ten years. By then they have been on the Moon long enough to prove themselves -- to have paid their dues as productive settlers who are apparently there for the long haul. This may seem to be an extravagant perk, but the very possibility already seems to be working magic for morale and attitude. The "Lunan Dream," it's being dubbed!

The point is that these homesteads are to each have their own interior garden "Earthpatch" spaces, as the homestead program hype has it. And that means that the proud owners-to-be will have their own private supply of garden stuffs out of which they can experiment making various things. For the rest of us, this is still a powerful dream, but we can get some kinds of inedible biomass items from the farm units for child (or adult) "art du jour" and other "ephemeral purposes." The idea is that this "detour on the way to the compost piles or biodigesters" will have profound benefits, however intangible. The bottom line of the export-import equation is deeply affected by morale. The happy guy produces more.

Back to the tree and trimming it

Who says we have to have a recently live tree or even an artificial "lifelike" one? Small trees or shrubs can be decorated in place in the community gardens or in one's own homestead garden. An old missionary home from North Africa once told us how every Christmas, he would move a potted orange tree indoors and wrap the live oranges with foil. Not that we will be doing that exactly. The point is that if we are resourceful, many things are possible!

In addition to decorating living trees in place (whether they fit the pine or fir tree image or not) or movable potted trees, we can make tree-shape frames out of wire (someone could turn them out in quantity and they would sell like hitchhikes) and weave in cut or dried vines, branches, fruit and other garden stuffs. If you watch the Christmas season special craft shows on TV, you'll find plenty of inspiration for pre-holiday projects making your own decorations. Crafters have the spirit. They will find some way to use whatever is available and turn out something very special and beautiful.

When you think of it, where else but in the garden can we get the vivid reds and greens we need to manifest the season's colors. Foliage of all types for green. Peppers, berries and fruit for red. Maybe we could even grow Poinsettias!

Garlands and ornaments can be made from fabric (died with vegetable colors)(old clothing or sewing scraps) also, as well as from home-crafted paper. We can thread berries and dried fruit for garland. The possibilities are endless - again, just watch the seasonal craft shows for inspiration.

Christmas lights and candles

We need season mood lighting, but who says that has to be in the form of strings of lights? Wall-washers and sconces fitted with red or green stained glass diffusers should do, bathing walls with holiday cheer along with the "tree", of course. Slide-away stained glass diffusers in cheery bright colors could be used at each light port if you have a light pipe sunlight distribution system [MMM #66 June 1993, p. 7 "Let there be light"; MMM #136 June 2000. pp. 3-4 "Sulfur Lamps & Light Pipes"]. And why not backlit free-hanging holiday scene stained glass windows? Of course, the stained glass stuff will have to wait until our mining operations are producing the needed metal oxides (needed *first* as alloy ingredients.)

Candles would be a problem in tight unpressurized areas because of the gaseous emissions from burning wax. Clean-burning candles are an option to be used with very great restraint, probably for a few minutes only as in the start of a holiday ceremony.

Slide set screen savers on big wall-mount flat screen monitors or TVs in idle mode can show vivid holiday scenes to help with the ambiance. Cheery Holiday colors will not be a problem!

Boxes and Wrappings

Storage space is at a premium so any kind of crafted box would be a gift in itself, made of cannibalized sheet metal or ceramic or glass or papier-mâché. But why not wrap gifts in predyed or undyed fabric (or even in an item of clothing) as a gift in itself along with what's bundled inside? That's but an elaboration of the old "Christmas Stocking" idea! Strips of dyed fabric can do as ribbon. Home-crafted paper is a possibility for wrapping smaller items.

Gifts for giving and getting

What to give? Whoa! Better break old habits and start planning *way* ahead. "What to make?" is the question. But for those who've never been hands-on types, there will likely be quite a few fellow settlers only to happy to fatten their bank accounts at your expense by churning our craft items, clothing items, and gifts from the garden. And then there are the old cop-out standbys, gift certificates and checks.

Music, Maestro, Please!

Live and canned music from Earth should not be a problem. And homegrown made-on-Luna musical instruments have already started to crop up. With wood, brass and plastic unavailable, they are made of cannibalized sheet metal, glass, ceramics, etc. But as these are still hard to come by, *a capello* singing, unaccompanied by instruments, is already becoming a pioneer tradition. Holiday plays too, of course.

I'm beginning to feel better about my first Christmas on the Moon. But I can see that I have to break my shop-at-the-last-possible-minute habits. It's going to take some planning, but it is going to be special, even without the snow!

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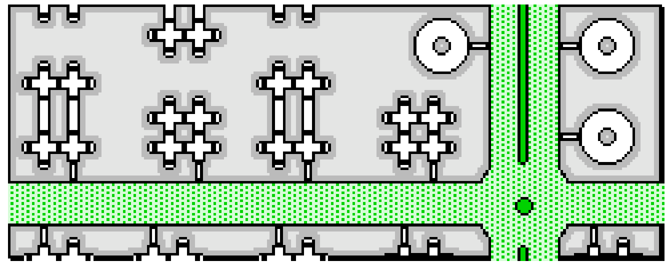
MMM #152 - FEB 2002



The "Middoors" as key Biosphere Component

In a modular settlement, allowed to grow as need be (not a fixed size megastructure based on someone's guesstimate of future needs), modular habitats and other structures are connected to pressurized residential/commercial "streets." These "commons" will contain the bulk of the settlement's biomass and biosphere. See "Being able to go Outside" *below*.

Homes "at home" on the Moon:
Thermally Self-Regulating Lunar Habitats with Backup Off-Grid Power Systems

by Peter Kokh

Impossible? We will feel more "at home" on the Moon if our homesteads are designed to *play the lunar thermal cycles* so as not to depend totally on any outside heating or cooling inputs. A power grid may be essential, but power grids fail. On Earth this is a matter of inconvenience: bundling up if it's cold, meat spoilage if it's hot. On the Moon a temporary power plant outage could be a death sentence for many, if not all, if there are no back up systems. And building a modular back-up capacity into each unit will certainly provide the best security of all.

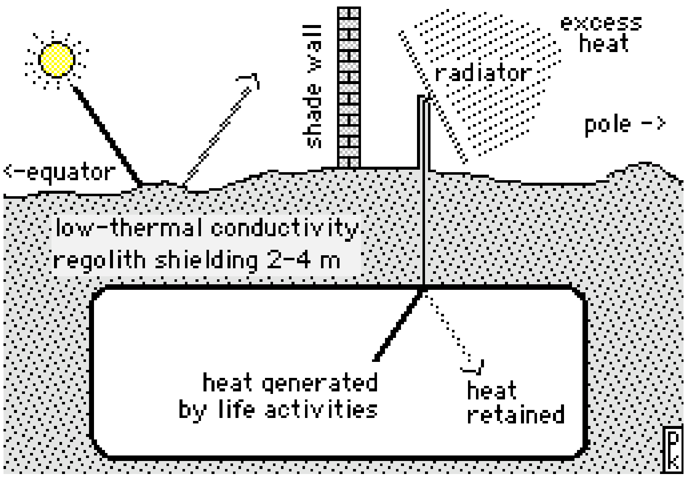
We are talking about thermal equilibrium as well as electric power generating capacity. This goal is not something new. There are a small but growing number of homes in this country whose architecture and construction materials attempt to achieve an analogous "environmentally tuned" balance, first as to thermal management, second with respect to off-grid power generation capacity. On the Moon, this may well be a goal that will not be achieved without a an even greater amount of trial and error experimentation. The time to begin brainstorming is now, however, as our security and survivability will be tenuous and fragile from the gitgo -- until we can start building in this fashion as a matter of habit. The reward will not only be safer settlements but the feasibility of small isolated rural outposts wherever they are needed -- *and they will be needed!*

Thermal Storage Systems

Paper studies of possible thermal storage systems can help to get a first read on the merits of competing approaches, the comparative difficulty of installation and the engineering and technical challenges of each. On Earth, architects and builders have come up with a variety of passive and active systems. Some of these *may* suggest analogous solutions that will prove workable on the Moon. Other solutions will prove to be uniquely terrestrial. But we should not limit our brainstorming to the exploration of the adaptability of schemes we have tried here. It would be rather surprising if we did not find some uniquely lunar solutions.

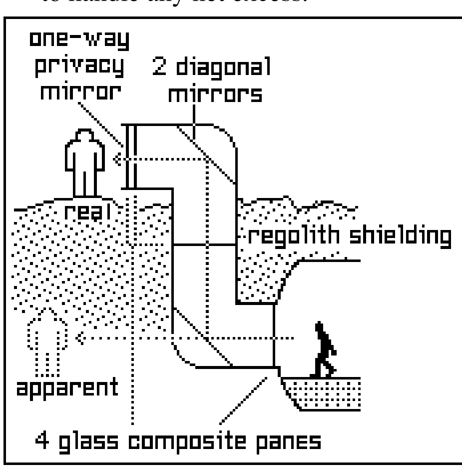
But to prime the reader's imagination, here are *some* of the more common thermal management techniques tried on Earth:

- **super-insulation** to keep out both excess cold and excess heat. On the Moon, that may not be enough, even if the stress of more extreme dayspan heat and nightspan cold is met. Daily living activities may produce a net heat excess that must be radiated to space to prevent steady heat build-up. Super-insulation *with radiators* are one approach

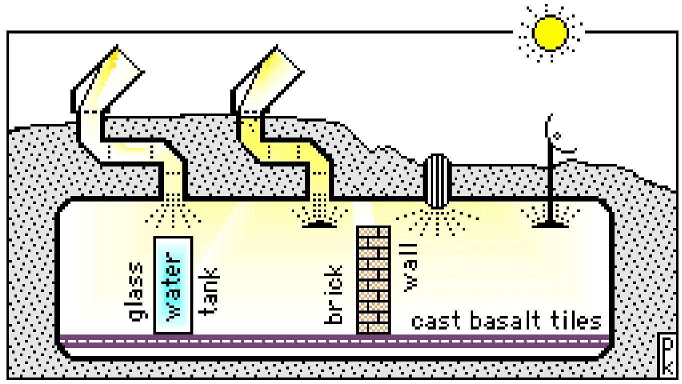


ABOVE: regolith shielding acts both to keep solar heat out of the habitat, and to keep heat generated by life activities within, Excess heat buildup is handled by shaded radiators shedding heat to the black cold sky.

- **passive solar** - allowing some solar heat to enter during the dayspan through periscopic windows and sun pipes that filter out most infrared wavelengths. This heat could be stored in massive reservoirs (cast basalt floor tiles, concrete hull, massive interior walls, water reservoirs etc.) for use during nightspan. A radiator system would still be needed to handle any net excess.

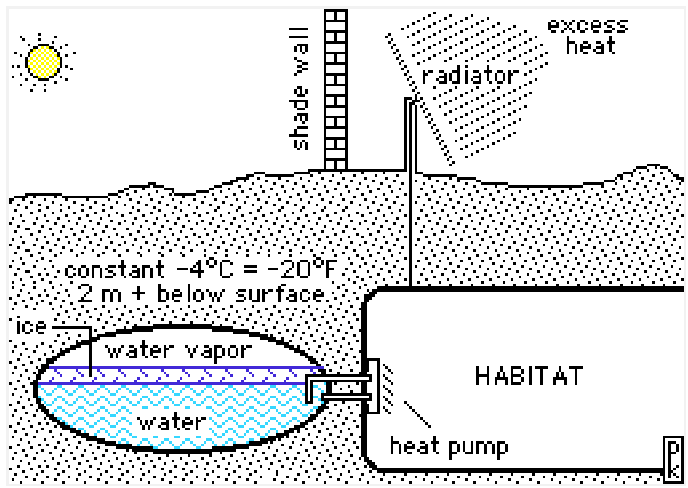


LEFT : there are several opportunities in the periscopic window system at left to filter out infrared heat bearing waves in sunlight - filter coatings on 3 panes and on 3 mirrors.



SHOWN: Controlled Passive Solar Inputs (heliostats and sun pipes with two types of light diffusers) and Thermal Storage Systems to radiate stored excess heat back into the habitat space in nightspan (massive floors, massive walls, and water reservoirs).

- **active systems using water reservoirs** to store cold as ice. Water is an ideal heat storage medium in itself, the more so because we will need to have an ample amount of it for biospheric stability. A water reservoir, connected to the homestead but exterior to it and insulated from the sun by two meters of more of soil, may be part of the solution. To shed excess heat, radiators may be needed. Want more of a challenge? Integrate semi-autonomous point source pre-treatment of waste waters.



- **active systems: magma-based.** If nightspan heating proves to be a greater problem than heat build-up, one system that could provide nightspan heat and power too, would use excess solar power capacity to melt regolith during dayspan, store it in a refractive alumina-lined cavity underground, and tap its heat (steam-powered generator) during nightspan. David Dunlop came up with this idea, and it may be more realistic for a neighborhood-scale habitat-cluster implementation.

Translating systems that work on Earth to something that will work on the Moon

We have but a layman's knowledge of thermal management engineering issues. Our purpose is to encourage those *with the expertise and terrestrial thermal management experience* to brainstorm how we might engineer stand-alone self-regulating lunar habitat spaces attune to the lunar dayspan/

nightspan rhythm that will function autonomously and worry-free off-grid, should there be a power interruption.

Not all of the great variety of schemes that have been tried on Earth with some success will successfully translate to unique lunar situations. But they are a starting point for brainstorming and we offer these ideas not to close discussion and experimentation but rather to begin it.

Electric Power Generation:
Cluster or Neighborhood Solutions:

In search of safety and security, we should look not only at individual pressurized structures but at the structure of the utility grids themselves. Centralization concentrates risk. A decentralized "cellular" grid structure with a "neighborhood by neighborhood" approach has advantages. By decentralizing power generation, building modular power generation plants so that each serves a cluster of pressurized structures or neighborhood, we provide a great deal of redundancy and resiliency. The fruit will be greatly increased "at home" peace of mind.

Whatever tricks we can master to maintain thermal equilibrium ought to include power generation survival systems that can operate off-grid for an appreciable amount of time, if not indefinitely. There are plenty of risks to pioneering the Moon. We need to minimize them, not increase them by over-dependence on centralized utilities that should be used to go beyond the minimum, not to provide it.

Off-Grid Electric Power Generation

If and when architects and structural systems engineers come up with plans that works to minimize the need for grid power to maintain a livable interior temperature range, we'll still need to address the question of providing autonomous off grid power systems for lunar homesteads for back-up insurance and safety for other electric uses besides heating and cooling -- communications, refrigeration, food preparation, etc. Every pioneer home should be able to operate *as if it were a small isolated rural outpost*.

Each habitat or pressurized space should have solar power panels of some type. These could be sized to provide a more than minimum power needed during dayspan -- enough extra to electrolyze waste water (thus recycling it at the same time) to run fuel cells for nighttime power *and fresh water*. This equipment should be a standard part of any habitat electrical system and a requisite for grid hookup.

Minimizing the problem:
Dayspan and Nightspan in the home

Even while the settlement power plants and grid are operating normally, pioneers may get in the habit of living at a different pace in the alternating two week long stretches of abundant sunshine and unbroken night. Even with a nuclear power plant, there will still be more energy available in dayspan when solar panels and concentrators are also at work. Production operations will concentrate on power-intensive tasks during dayspan, leaving manpower-intensive tasks for night, when and where feasible.

Within their homes, on their own time, it will make sense for Lunans to organize their household chores in like fashion, again where feasible. These go-with-the-flow practices and habits will provide extra resiliency in case of a grid power emergency, putting less strain on domestic backup systems.

The Reward -- In preparation and resiliency lies security, *and a sense of being "at home"*.

Reading from MMM Back Issues
#7 JUL '87, "POWERCO"
#43 MAR '91, pp. 5-6 "SUNTH Dayspan, Nightspan"

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Being "at Home" is Completed by Being able to go "Outside"

by Peter Kokh

No matter how cozy the home, if you are a virtual prisoner inside, your sense of being "at home" will be most uncomfortably limited. But "outside" on the Moon means out on the vacuum-soaked, radiation-washed surface -- or does it?

The Concept of the "Middoors"

[A synopsis from past MMM articles. See list at end.]

Thanks to the appearance in recent decades of enclosed climate-controlled shopping malls, the idea of some-thing in-between the indoors and outdoors (a distinction as old as man) is now familiar to most of us. The "middoors" [i.e. between the doors of homes, offices, shops and the doors to the natural outdoors] is also prefigured in the landscaped, sunlit atriums in new hotels, office buildings and even cruise ships.

The beachhead science outpost will be simply a pressurized indoors up against the outlocks vacuum, the "out-vac". Whether in a government outpost or in an early company mining town, the construction of the first spacious atrium solarium garden will introduce a new kind of space - a space external to individual quarters, lab modules, and other work- and function-dedicated pressurized places, yet still keeping out the life-quenching vacuum beyond the airlocks and the docking ports. What we have called the "middoors" will be born.

From this humble beginning, airy, spacious, verdant middoor spaces will grow to eventually host the greater part of the settlement's atmosphere and biomass. And with it, the hoped for "biospheric flywheel" will become much more of a reality.

It is within such spaces that longer, wider sight lines will appear, offering postcard views and vistas, to dull the edge of early day claustrophobia. The settlement will begin to take on the trappings of a little "world", a continuum of varying horizons. The effects on settler morale will be considerable.

In Lunar cities, except to enter and exit those industrial facilities which for safety's sake must keep their air unmixed with that of the city at large, it will be possible to go most anywhere without donning a space suit. Homes, schools, offices, farms, factories, and stores will exit, not to the airless, radiation-swept surface, but to a pressurized, soil-shielded, indirectly sunlit grid of residential and commercial streets, avenues, and parkways; parks, squares, and playgrounds; and pedestrian walkways.

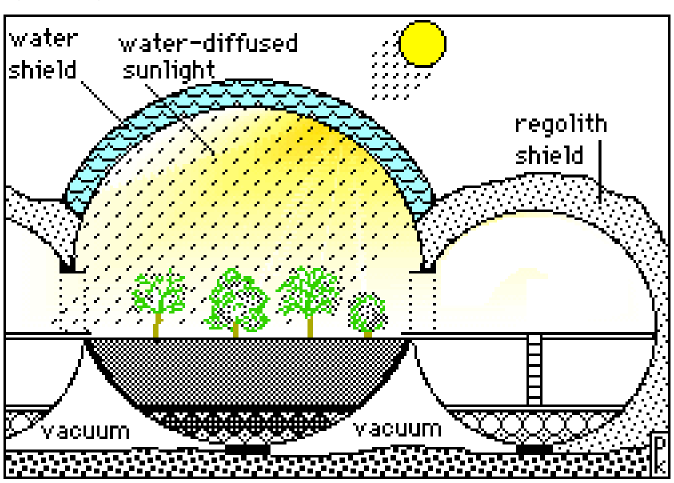
While the temperature of "indoor" spaces could easily be maintained at "room comfort" levels, that of the inter-connecting middoors of the city could be allowed, through proper design, to register enough solar gain during the course of the long Lunar day- span and enough radiative loss during the long nightspan to fluctuate 15 °F on either side, for example from 55-85 °F during the course of the lunar sunth.

Middoor spaces could be landscaped with plants thriving on this predictable variation. This would be invigorating and healthy for people, plants, and animals alike, providing a psychologically beneficiate monthly rhythm of tempered mini-seasons. Of course, the middoors could be designed to keep a steady temperature. Oh how boring that would be!

For perhaps the greater part of the population, the creation of generously-sized pressurized commons, nature and picnic parks and playing fields and parkways will satisfy everyday needs for the "outdoors." Sheltered from the cosmic elements, such spaces may nonetheless have an airy, suppor-tively verdant feel to them. Such public common spaces form a matrix within which the indoor spaces of homes, offices, shops, schools, and factories can literally "breathe".

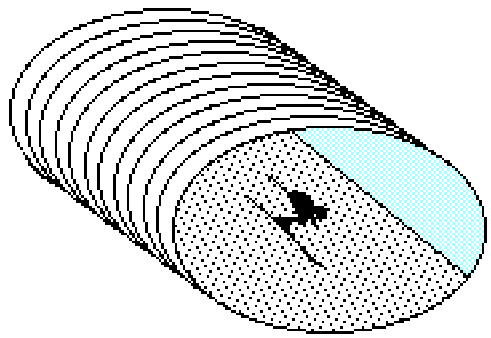
The more generous and more high-ceilinged spaces of the Lunan middoors can be realized by several architectural devices. Pressurized cylinders carrying vehicular traffic can have a radius generous enough to support green strips with hanging gardens, trees, walking and jogging paths, even meandering trout and canoe streams. Spherical or ovoid or torus structures can serve as more self-compact nonlinear park and nature space. Farming and food production areas can host public footpaths and picnic oases.

Sunshine ingress can be provided by bent path heliostat "sundows", by optic fiber shielded "sunwells", or more radically, as Marshall Savage suggests, by water-jacketed double domes.



Well-designed middoor spaces in a generous acre per citizen ratio can probably substitute for the open-air green-spaces of Earth for a large cross-section of the settlers. Others will need to come to personal terms with the out-vac. Still others will never be able to leave behind the green hills, the ocher deserts, the blue skies, the thick forests, the horizon to horizon expanses of ocean deep of the home world.

We will be able to walk, hike, bike, skate, row and trout-fish in lunar middoor spaces. Cherished outdoor activities that are more challenging to replicate but seem eventually doable include skiing and tobogganing in pressurized tubes positioned on the slopes of craters (see "Skiing the Moon" MMM #115 MAY '98).



Also doable is manpowered flight. Out of the question, at least in the early days of settlement are activities like powered flight and soaring, sky-diving, motor-boating, sailing, ocean cruising and hunting for example. We'll be able to go caving or spelunking in lavatubes, but in pressure suits.

Each person pondering signing up for the lunar frontier must weigh his or her attachments to cherished acti-vities that may not be supported in lunar settlement biospheres any time soon, if ever at all. Those taking the plunge will owe it to themselves to be politically and civically active in guaranteeing that the settlement middoors is as generous and diverse and user-friendly as economically possible. Nothing less than the morale and mental health and long-term survivability of the settlement is at stake.

While tightly climate controlled "indoor" spaces may vary but slightly from comfortable "room temperature" and humidity levels, the middoors may be designed to swing freely from a late pre-sunset dayspan temperature that is tolerably warm and humid, to a late predawn nightspan temperature just enough above freezing not to harm the various plant-forms within. "Sunthly" "weather" patterns will add welcome variety and spice to day-in, day-out life.

That favorite conversation-making unpredictability of terrestrial weather, however, may be hard to program in. If temperate food plants are desired, perhaps an annual hard frost might be arranged one nightspan a year, as part of a partial cleansing freeze out of accumulating atmospheric pollutants and impurities. It's a thought. And depending on ceiling heights of the street vaults, any gradual increase of humidity levels beyond a certain point might trigger mist-making condensations, say sometime after local sunset. At any rate, such middoor "weather changes" will help keep the populace healthfully invigorated, as well as supplied something innocuous to complain about. A fringe benefit will be a whole new cottage industry to create fashionable "outerwear".

Conclusion

The Middoors is an essential concept with a critical function in the design of lunar settlement mini-biospheres. Middoor spaces will include parks and parkways as well as agricultural areas, and thus host the lion's share of the settlement's biomass. Air circulation in the middoor maze of interconnected pressurized public spaces, markets, parks, walkways and streets will be an essential part of the air recycling system. Reserve waters as well as largely pretreated waste waters will also circulate through the middoors as part of the water purification system, providing fountains, waterfalls, trout streams, duck lagoons, and more.

Meanwhile, the middoors, even in modular settlements built unit by unit as needed (as opposed to vulnerable fixed-size megastructures so common on science-fiction rag covers) will go a long way to prevent the build up of cabin fever malaise. In contrast to habitat modules, the larger diameter cylinders for roadways, bike paths, public transit, and roadside plantings, and even larger spherical, ovoid, or toroidal plazas, squares and parks will boast higher ceilings and longer sight lines for welcome eye relief.

There will be those "hard core" outdoor types for whom this will not be enough. And that is great. Their enthusiasm and relentless search for ways to make themselves "at home" in "Out-Vac" sport and field activities out under open black skies will end in pushing the envelope even further. That will be good. The wider the cross-section of normal personality types that can enjoy satisfying lives in lunar environments reclaimed from wasteland, the more truly viable will lunar settlement become long term .

Meanwhile, lunar settlement Middoors spaces will allow Lunan pioneers to feel "at home" outside their homes as well as inside them.

Relevant Readings from Back Issues of MMM

5 MAY '87 "M is for Middoors"
8 SEP '87 "Parkway"
37 JUL '90 p 3, "Ramadas"
55 MAR '92 pp 4-6 "Xity Plans" - *illustrated*
74 APR '94 p 7 "Sun Moods" - *illustrated*
89 OCT '95 pp 3-4 "SHELTER on the Moon"
94 APR '96 p. 4 "Vac, Out-Vac, Lee Space, Middoors"
96 JUN '96 p. 6 "Spacesuit Aversion"

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Homo Lunensis

"We must develop the habit of dealing
with anything and everything lunar
in such a way
that the Moon becomes a place
where we will have learned
to become truly native."

Security Comfort Levels:

We won't be "at home" on the Moon until the Know-how to Maintain our Presence is Widespread among the Pioneer Population

by Peter Kokh

In every culture throughout time, there have always been elders or an elite with special critical knowledge vital to the survival of the community. At the same time, other skills and know-how are often commonly widespread in the population.

In our own society there are the nuclear scientists and brain surgeons and other experts f esoteric domains - a relatively small group of highly trained individuals. But there is still a considerable body of vernacular know-how: auto repair, home repair and construction skills, day in - day out ability to use computers for a whole list of purposes, farming skills, and many more "trades" too numerous to mention. And then there are specializations, even of things once commonly known, simply because life is so complex no one can know even the basics about "everything" -- how to make soap for example.

We have become ever more dependent on higher and higher technology. Yet that dependence extends only to quality of life. Without it, we'd be knocked down a few pegs to a cruder, simpler time. But our survival would not be at issue. On the Moon and Mars, however, the stakes will be radically higher. We will be dependent on high technology for our continued existence at every moment:

- maintenance of pressurization and seals
- constraints on lunar architecture / construction
- maintenance of ever more heavily biologically-assisted life support systems
- plumbing and ducting systems that assist in the refreshening of the air and the water
- biomass recycling and recovery
- last but hardly least, maintaining a positive import-export equation.

Our thesis in this article is that our security on future adopted worlds will depend on such kinds of essential know-how becoming, and remaining, widespread among the settler population; and that virtually everyone needs to understand the basics. Why? Because without citizen cooperation, the efforts to maintain these vital systems will be at real risk eventual failure. For example, the best engineering possible of water, air, and waste recycling will be defeated without strong public cooperation.

On Earth, these are important issues. But system failure is not a matter of life and death that threatens near term. Our planet gives us a generous biosphere. On the frontier, we have to provide this and maintain it ourselves. We cannot risk a settlement population becoming a misguided rabble.

The Role of the Settlement Schools

Broad knowledge of the system of special expertise, systems, and engineering that make life in the lunar or Martian settlement possible can be guaranteed, by a simple plan, rigorously pursued.

Starting in the earliest years, children can be introduced to the basic ideas behind human-created and maintained mini-biospheres and the systems that make them work: abundant plant life, the food production system, water and air treatment, etc. The concept of the pressure hull and threats to its integrity. Simple lessons and explanations at first, but as the children grow older, each subject should be revisited in ever greater detail. What starts as a lesson, in time becomes a whole course. Periodic field trips to the settlement's utility facilities will help, with revisits as the child is older and can comprehend in greater depth.

Meanwhile, at home, children can take turns with housekeeping chores that help make the system work. Older kids can help sort recyclables, repair salvageable items, even disassemble products whose components need to be recycled separately.

Universal Service

After secondary school, young people could do a stint of universal service in any one of several vital areas:

- □ hull pressurization patrol and maintenance corps
- □ yeoman duty with architectural and construction firms
- □ agriculture & biomass recycling
- □ the water works
- □ inorganic recycling utility, etc.

The result of such mandatory service (for a length of time to be determined by the settlement) would result in very widespread appreciation of what it takes to maintain human presence on the Moon or Mars. And therein lies security.

At the technical school and university level, individuals who feel the call to be at the forefront of one of these vital fields, can pursue studies further: **Settlement Systems 101** as an in depth introduction to all these vital systems would be a prerequisite to advanced courses and majors in any one of them.

The risk of ill-fated political decisions with unsuspected consequences that threaten the state of any of the settlement's essential systems, will be much less if the populace as a whole have a high degree of appreciation for what is at stake. On Earth we take the long term existence of our cultures and their towns and cities for granted. To be sure, we have our ghost towns, places where something stopped working (generally the economy). On the space frontier our presence will always be tentative. our future a presumption.

There can, of course, be no guarantees. But if the population at large is engaged in what it takes to continue to win against the odds, the chances of continued success will be that much greater. Without this broad widespread appreciation, the chances of an end to human presence on the Moon, a string of ghost towns in our wake, is high. Do it right, and we will be, and feel, "at home."

Lighthouse Network for Travelers

by Peter Kokh

In MMM # 151 DEC '01, pp. 3-6 "Engaging the Surface with Moonsuits instead of Spacesuits" we suggested that Lunar GPS units be standard equipment. Yet, the Moon being the *unforgiving* environment that it is, redundancy is the wisest policy.

So we pose the question: how would "lost" or location/direction-confused travelers, explorers, prospectors, and other people in the field find their way to their destination, or back home, if for some reason their GPS unit was not working, or the system was down (satellite failure)?

An updated and Moon-adapted analog of the time-revered lighthouse network along the coastlines of Earth's oceans and Great Lakes might be useful, particularly in analogous "coastal" areas of the Moon. The Moon's "seas" -- plains of congealed lava that fill great impact basins -- are bordered by impact basin ramparts and highlands with intermittent high points or "headlands." Travelers taking coast-hugging routes could benefit from a chain of well-placed lighthouses. In time, a network of such beacons could be placed on high points along cross-highland routes as well.

By "Lighthouse" we mean:

Before we go any further in this seemingly romantic reverie, let's make clear what we do and do not mean by a lunar "lighthouse." These would not be manned, nor would they be eternally "lit" as are our terrestrial analogs. Nor need they be as large.

The lunar "lighthouse" we envision normally sits passive, "on call" when needed. An omnidirectional radio signal from a confused traveler would awaken any lighthouses in line-of sight. Each would then send out a directional homing beacon signal that would contain a "signature" identifying it to the traveler to help in determining his/her location. A visible light pulse could also be emitted when the lighthouse was in darkness or shadow.

These units would have solar panels to keep batteries charged, with enough of a charge to work when needed during the long nightspan stretches. Once in place, they would operate "on call" indefinitely without tending, and without grid connections.

Samples of placement:

We have made line sketches of two areas where such networks might be useful in the earliest frontier period -- proposed areas of early settlement. [Discounting the Poles as totally atypical regions that are likely to be dead-ends.]

1. the coastlines of "Angus Bay" (Mare Anguis or the Sea of Serpents) and the adjoining NE coast of Mare Crisium (Sea of Crises
2. the northern coastline of Mare Frigoris (Sea of Cold), a prime settlement location ("North Junction") -- and high points along one possible cross-highland route to the North Polar Icefields and the "white gold" they contain.

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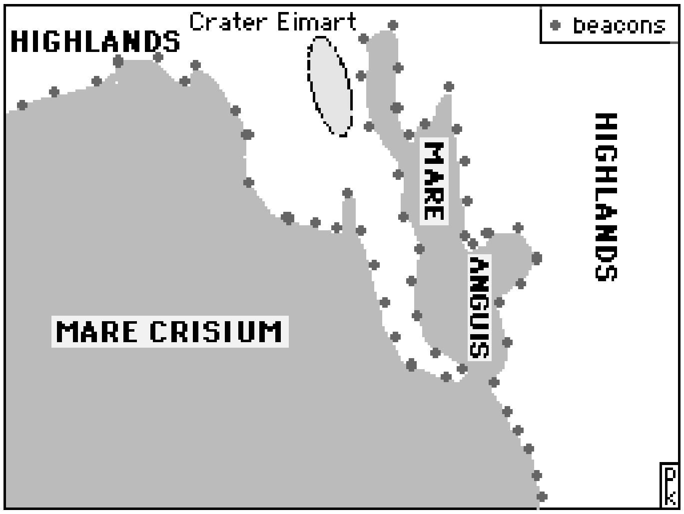
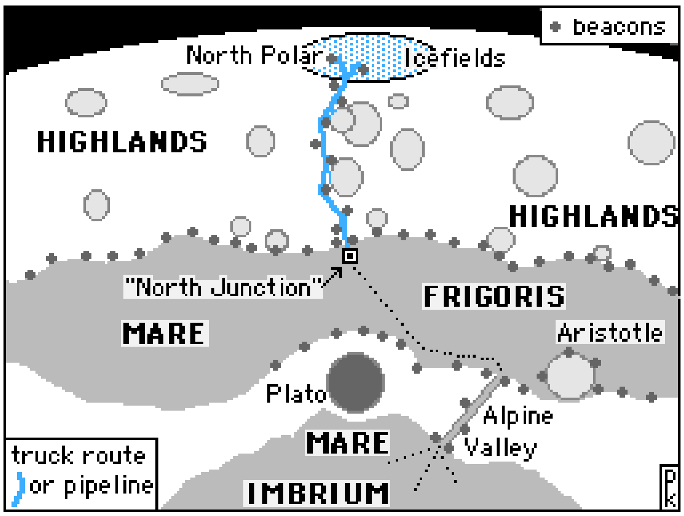


Beacons along the Crisium & Anguis "coasts"



Beacons along the Frigoris "coast" & Alpine Valley

Such automated "lighthouse" beacons could be small and relatively lightweight which would help in deployment. The first explorers to blaze any trail through "virgin" terrain would set them at surveyed high points so that the network would grow steadily with the expansion of "explored" terrain.

Could we package such beacons in inflatable tetra-hedrons (we don't want them to roll back downhill much less down the opposite slope) so that we could hurl them precisely to their intended perches without having to scale hills our-selves? Within such an envelope, the equipment package would be self-upright itself, then deflate the cushioning envelope.

Along level terrain routes with no real high points, beacons can be hoisted up telescoping pylons -- after all, on the Moon the horizons are much closer than on the larger Earth. On this windless low-G world, such pylons could be very lightweight.

Such a system could be the prime carrier of commu-nications and data *in, from, and to* the deep Farside where we will want to maintain high radio quiet for Radio Telescopes. It's all part of making the Moon *a friendlier place to call "home."*

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MMM #153 - MAR 2002

Aviation on Mars - A Task Force & A Plan

Above, NASA's solar-powered unmanned Helios Prototype on its way to a record altitude of 96,863 feet on August 13th, 2001. Its 247 ft wingspan carried a payload of 100 lbs. to an altitude where Earth's atmosphere is as thin as Mars'. A new breed of planes will open the planet's vast roadless reaches to daring human pioneers. =>> *below*

In Focus ▣ Mars and NASA's new "Nuclear Systems Initiative"

Editorial Essay by Peter Kokh

A central feature of NASA's new budget is its "Nuclear Systems Initiative." NASA explored several nuclear propulsion ideas back in the early seventies, but this effort, perhaps premature, fell victim to Nixon's cost cutting ax. So we have been hobbling around the solar system relying almost exclusively on chemical rockets. Even pushed to their theoretical performance limits, chemical engines are severely limited in what they can do. They permit us to crawl to Mars, the asteroids, and the outer planets with barely enough instrumentation to make these efforts worthwhile. While what we have learned from the Voyagers, Galileo and various Mars missions along with what we hope to learn from the Cassini-Huygens mission to Saturn and Titan is most amazing.

We have, however, only scratched the surface. Galileo's multiple orbits of Jupiter through the realm occupied by its four great moons has revealed four worlds each deserving of its own dedicated fully instrumented orbiter and a fleet of landers. Europa, especially, deserves as much attention as we have been giving to Mars. It is most likely, moreover, that Cassini will reveal Saturn's moons to be equally deserving of intensive, dedicated further study.

Yet up to now, only two more outer system missions have been under consideration: the Pluto-Kuiper flyby, and a first Europa orbiter. Both have been so constrained by unrealistic budgets, that the amount of science either would be able to deliver, while very welcome and surely enlightening, succeed mainly in intensifying our curiosity even further. Both these targets are worth major missions, not lightweight token efforts. But given chemical rockets and the distances to be covered, we are limited in our achievements.

We have always been strongly supportive of near term missions to both Pluto and Europa. But perhaps it is time to take a longer, more patient view. Do we want to learn the little we can in the next 10-15 years, with slim chance of follow up missions to answer the many major questions both these limited teaser probes would raise? Or is it worth putting both these exciting chemical rocket missions on hold while we develop significantly superior nuclear electric propulsion engines that in the long run, promise to offer us much more science in a decade or two than we can hope to gather with another century of reliance on chemical rockets?

What is under consideration, is development of a uranium-fueled nuclear fission reactor with an advanced electric propulsion system that energizes a set of ion engines. Safety will be paramount:

- the nuclear reactor would stay intact in the event of a launch failure.
- the nuclear hardware is to be launched in a "cold", non-operating state.
- The reactor (of any future spacecraft mission) would be activated at nearly 1,555 miles (2,500 kilometers) distance from Earth. This high, non-decaying orbit altitude was chosen to be compliant with the NASA Orbital Debris Guidelines in case the system failed to start.

Sean O'Keefe, NASA's new administrator, is making a gamble that many are unhappy with. Two most scientifically important missions are being put on hold for the development of a propulsion system which may take longer than expected to perfect. Even many of those who applaud NASA's Nuclear Systems Initiative for its unquestioned promise, feel that this new emphasis does not justify scrapping two conventional missions already well into their planning stages. Indeed, given the way the Bush administration is spending billions futilely strengthening *only some of many weak links* in our defenses, it is disturbing to see worthwhile initiatives cut to pay the price.

We'd very much like to be around when the first Europa orbiter peeks below that moon's ice crust to confirm and map the ocean below. But we'd be even happier if we knew that we had developed the technology to open the outer solar system to routine science missions that would enable much more thorough exploration.

Nuclear electric propulsion for unmanned probes is just the beginning. If humans in the flesh are ever to go beyond Mars (or to go beyond exploration of Mars to opening it up as a new frontier) we will need a faster, and safer, means of propulsion. Safer? Yes, because shorter trip times mean less total exposure to the radiation hazards of space.

Nuclear thermal rockets could cut trip time to the Moon to 24 hours (instead of three days), one way to Mars down form 6-9 months to perhaps three. At the same time, the faster propulsion would work to lengthen launch windows significantly. Humans to Mars by chemical rockets is possible, just! Longer missions to the asteroids and beyond would stretch this old revered technology to the point of suicidal absurdity. If we want an open ended future for humans in the solar system, we have no choice but to get beyond the infancy of our "Space Age."

Patience is a difficult virtue to practice. It does not mean siting around waiting. It means aggressively working for better options. We owe this to ourselves, to our dreams.

Go NASA, go! - PK

To Mars by way of La Paz

No, not Mexico, Bolivia!

by Peter Kokh

The Search for Mars Analog Locations

We've all heard of other "Terrestrial Roads" to Mars:

- *to Mars via* the Dry Valleys of Antarctica
- *to Mars via* Canada's Devon Island (FMARS)
- *to Mars via* Hanksville, Utah (MDRS)

All these places have their analogies to Mars. The Antarctic dry valleys are very cold and ultra dry, as close a climatic match as is to be found on Earth. But the logistics between here and there leave much to be desired.

Devon Island is remote, but in comparison to the Dry Valleys, practically in our back yard. here the analogy is not so much the climate but the terrain, and paucity of vegetation.

South Central Utah is red rock country and also has vegetation-free areas. Plus it is in easy reach of Salt Lake City, Las Vegas, Albuquerque, and Denver.

Why add La Paz, Bolivia to this list?

Because on Mars, the air is thin -- as thin as it is between 100,000 and 125,000 feet up here on Earth. That's something it's fair to say that most of us will never directly experience. Sure there's Mount Everest and our own Mount McKinley, and closer to home to most readers, Pike's Peak in Utah at 14,002 ft. (I've been there myself.) But these are all uninhabited places.

La Paz, Bolivia, is the world's highest capital city at 12,000 ft. nestled in the Altiplano valley between parallel ranges of the mighty Andes. And now suddenly well over a million in population, it is also the world's highest major city, significantly higher than Cuzco, Quito, Nairobi, Bogota, and Mexico City, in descending order. [For nit-pickers, much smaller Lhasa in Tibet is a 100 meters higher.]

La Paz' J. F. Kennedy Airport, at 13,800 feet is even higher. But that's a lot lower than 100,000 ft. let alone 125,000 ft. But for the current bunch of major human settlement's, La Paz is as close as this planet has to offer.

Curiously, one of the nearby scenic musts is Vale de Luna, Valley of the Moon. With its Mars-hued rocks, perhaps it is misnamed! For a glimpse of this scenic treasure, go to:

http://www.cogs.susx.ac.uk/users/fabricer/
trips/bolipix/profond.gif

To Mars by way of La Paz? The point of course is that if you think that 12,000 feet up is too high, then maybe you had better think twice about going to Mars.

But if you are looking for a vacation trip out of the ordinary and that will put you in a Mars mood, why not here? One thing is for sure. You can have much more fun in La Paz than in Antarctica, Devon Island, or the middle of nowhere in Utah!

Just thought you'd want to know. :) **<MMM>**

Mars Aviation Task Force

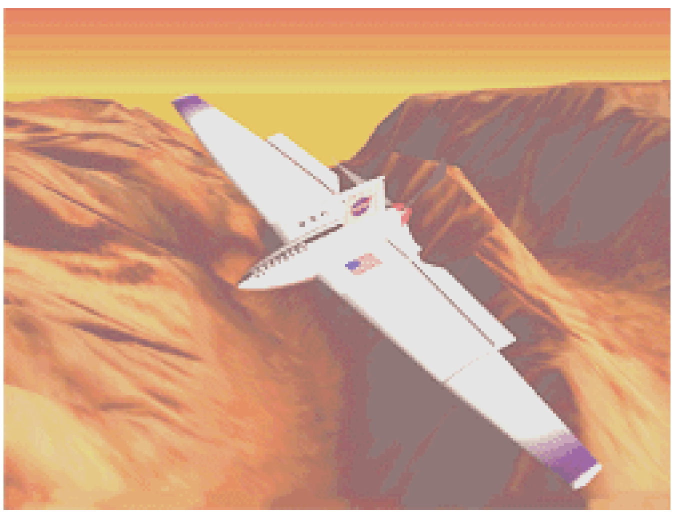
A Mars Society project for exploring the design issues, the relevant framework, and the operational characteristics of an airborne transportation system on Mars.

by Paul Swift (pswift@shaw.ca)
and Peter Kokh (kokhmmm@aol.com

Segue form the piece above -- Peter Kokh

The highest major airport on Earth with regular scheduled jet service is La Paz, Bolivia's J. F. Kennedy International airport at 13,800 ft. It was a milestone of aviation history when the first Boeing 727 arrived. Now if that was such a feat, how can we be serious about flying on Mars where the air is as thin as it is at 100-125 thousand feet up on Earth?

Despite the tremendous challenge and many hurdles, there is quite a bit of excitement, *and confidence,* that we can learn to do just that! NASA has several unmanned Mars drone plane probe designs in the works, including the *KittyHawk*, which would be on its way next year for a maiden flight over the immense Valles Marineris canyon on December 3, 2003 as part of a celebration of the 100th anniversary of the Wright Brothers famous first flight -- *had it not been for the Mars Polar Lander fiasco*.



On August 13th, last year, NASA's solar-powered unmanned Helios prototype reached a record altitude of 96,863 feet, where the air is about as thin as it is on Mars. (See page 1, bottom, this issue.)

But aviation designers are looking beyond lightweight unpiloted exploration craft. For more than fifteen years they have been brainstorming just how we can achieve piloted flight on the Red Planet.

What's at stake

On Mars the role of special airplanes will not only be to assist truly global exploration of this intriguing world, but to be the workhorse of expansion of a human frontier on Mars to territory as vast as Earth's seven continents combined. The trackless surface is a veritable minefield of boulders, and creation of a global road network would be slow and expensive.

Large aircraft that could take off and land vertically carrying runway-building equipment would open the planet by building runways that could then be used by conventional aircraft of various types.

Unlike the situation facing Lunan pioneers, an "umbilical cord" to Earth is not feasible. The governing paradigm will be that of the "egg and yolk sac." Because of the long 25+ month wait between launch windows, plus additional wait for return windows, reliance on Earth-based rescue, repair, and relief would be a recipe for certain disaster and failure. The first expeditions will have to bring with them whatever resources they may need to fall back upon in order to recover from mishaps and disasters.

Once we commit to the establishment of an open-ended frontier community, it will make much more sense to develop a broad diversity of local resources. If you need copper, for instance, and there is none in the local soils, you will want to be able to access such a resource elsewhere on Mars. In other words, an interdependent plurality of settlements scattered over the Martian globe will be much more viable and self-reliant than any possible single site.

Roads can and will be built in and around the various settlements. But we will need to "leapfrog" hundreds and thousands of miles/kilometers of intervening trackless, rugged terrain to forge scattered settlements into one diversified Martian economy.

For this task, Mars aircraft will be essential. We will need planes for prospectors and geologists seeking to verify and pinpoint strategic resources: metals, alloy ingredients, water, thorium and uranium, etc. We'll need VTOL search & rescue craft. And cargo planes to ship specialty manufactures from one area to another. Passenger airliners too.

Without planes, to reach and explore a remote site, one would have to return to Earth and launch again to a new site - sheer folly!. Yes, flying on Mars will pose great risks. The fearful can stay behind. It is absurd to think of opening a frontier without risk.

If we want to open Mars, it is essential that we soon fly drone scout aircraft on Mars, and then quickly begin developing human-piloted craft. Our goal should be to have such a craft included in the first Mars Landing mission. Aim high, hit the mark!

Readings:

Dirigible Airships for Martian Surface Exploration by W. Mitchell Clapp. AAS 84-176. Case for Mars II, Ed. Christopher P. McKay, 1985, American Astronautical Society ISBN 0-877030220-3, pp 489-96.

Nuclear Thermal Ascent Vehicle Using Indigenous Fuels for Multiple Takeoffs and Landings (NIMF) by Robert M. Zubrin, pp. 17-28, Proceedings of ISDC '89, Ed. Jeffrey G. Liss, Univelt, ISBN 0-912183-09-8

Mars Airplane Design Studies, Kenneth R. Silver and Michael F. Lembeck, pp. 204-15, ISDC'89 op. cit.

A presentation by Paul Swift, Mars Convention 2000

The Mars Aviation Task Force - Paul Swift

This is a formal announcement that the Mars Society will be hosting a unique discussion group on the topic of traveling through the 'air' on Mars. Specifically, this discussion group will consider all aspects of crewed airborne transport on Mars.

The Martian environment will require a multi faceted approach to enable humans to move about the surface of the planet. It is acknowledged that aground transportation segment will be a vital and necessary subsystem of this Mars Transportation System, but is not a part of this discussion.

The time is now here to start to formulate the types of missions that will be undertaken by the first comers to Mars, as well as the groups to subsequently come doing their extended work.

Discussions are expected to focus on some of these following issues:

- The Martian aerial environment
- Base camp and 'fly' camp placement and servicing
- Crew and passenger selection and functions
- Mission definitions
- Range and capacity of aerial vehicles
- Speed and payload capability
- Landing, takeoff limitations and requirements
- Fuel system management
- Propulsion and structural requirements
- Crew safety procedures
- Search and rescue etc.

The reason for putting this list into action now is simple. We will soon be overtaken by events unless we are very proactive in this area. The time to define the Airborne segment of the Mars Transportation System is now. We have the capability of specifying what is needed, building and testing it here on Earth, while learning perhaps some new skills and putting our theoretical approach into practice.

- Hardware proposals include wing supported airplanes, rocket supported aerodynamic vehicles as well as non-aerodynamic vehicles.
- Propulsion varies from propeller driven to rocket or steam jet, or an engine that may use certain elements from the Martian soil or atmosphere.
- Fuel categories include chemical, solar, nuclear.

Listed here are some of the missions that will help determine how we think as designers of aircraft:

- Long range recon - eyeball & camera plus sensors
- Mapping • Cinema-photography
- Landform examination (outcrops / anomalies)
- Outpost servicing • Search & Rescue
- Point to point delivery/pickup of people/supplies
- Fuel depot management • Atmosphere research

And probably more. These require characteristics in the flight vehicle vastly different from one another, including speed. Some of these missions will require flying as fast as possible, while for others it will be hard toy fly slow enough. Some flights will carry only a tiny payload, while others must have massive cargo capacity. I foresee several aircraft types, one for each type of mission. The low level Mark I Eyeball terrain recon mission at low speed and highly maneuverable (my pet project.) Medium range search & rescue high speed vehicle for point to point operations. Heavy lifter for outpost construction and resupply.

The area of field maintenance is extremely critical. But it all boils down to the design. Is it built to be manufactured cheaply, or built for easy field access to all components? You can squeeze by on Earth, but flying over Mars, mechanical problems must be field-solvable. A staffed and well-equipped hanger may be half the globe away.

[As a preliminary reference document, the content of a presentation by Paul Swift to the Mars Society membership at the 3rd Annual Mars Convention in Toronto in 2000 is on this site for consideration.]

Where to find us

We may or may not have the Mars Aviation Task Force website and email discussion group up and running by the time this issue of MMM arrives in your mailbox. Our target date is mid-late April. And here are the addresses we have reserved:

http://MarsHome.org/MarsAviation

MarsAviation-Subscribe@lists.MarsSociety.org

Nontechnical assistance needed -- Peter Kokh

If you think that flying on Mars is a great idea but are not an aviation engineer, we can still use your help. Two early priorities for the Mars Aviation Task Force do not require technical proficiency:

1. Compile an exhaustive **bibliography** that will be accessible online covering
   a. Papers on Aviation on Mars
   b. Papers on Aviation on Earth at very high “Marslike” altitudes
2. Compile an **image library** accessible online of appropriate artwork to include serious sketches of Mars Aircraft design ideas but also historical and fictional art in the “inspirational” category (Bonestel’s depiction of Von Braun’s great winged Mars Landing Craft, for example.)

Outreach & Recruiting Opportunities Galore

The immediate spark behind this effort is an opportunity in Milwaukee. *Aviation Career Day* is an annual event held at Mitchell Field International Airport every year on the last Thursday evening / Friday morning each April. At last year’s event, we reserved a table for the Wisconsin Mars Society chapter & LRS with the theme “You can fly on Mars!”

Aviation and Experimental Aviation enthusiasts are an enormous untapped resource. In every part of the country and abroad there are annual Air Show events at which, following our model, chapters of the Mars Society and National Space Society can get the message across: *“We Can Fly on Mars!”*

<MMM>

Mining Mars' Atmosphere as *if* our survival depended on *it!*

by Peter Kokh

Mars' atmosphere is 97% carbon dioxide, the rest mostly nitrogen, with some argon and traces of water vapor. Thin as it is, this "air" is thick enough for aerobrake assistance in landing from orbit, or on direct trajectories from Earth -- saving fuel. We are also confident that it is just thick enough to support flight. And from this atmosphere we can derive both oxygen and nitrogen to provide breathable air in our pressurized outpost and settlement structures. These are three critical pluses for the exploration of Mars.

But the usefulness of this thin envelope does not end here. Its chemical feedstock potential will help pioneers make do without the fossil fuel bounty to which we have become addicted on Earth. Robert Zubrin's ISRU [in situ resource utilization] experiments, repeated successfully by others, show that we can use Mars' air to produce *useful fuel combinations:* carbon monoxide + oxygen; and the more potent methane (CH_4) + oxygen. These bottled or liquefied fuels will run generators for electric power, operate machinery, and provide fuel for Earth return craft, surface transports, and even aircraft.

Power for generators and fuel for vehicles are extremely important. We will need both right away, and having to bring along from Earth only the capitol equipment needed to produce these fuels rather than fuels themselves, will not only make early missions that much more doable, but lay the groundwork for successor missions and outpost expansion.

Chemical industry feedstocks

On Earth, we rely on petrochemicals not only for fuels, but also for feedstocks for our diversified chemical industries, *even for pharmaceuticals*. If a frontier is to be established on Mars, we will need some way to kick start the local equivalent of a petrochemicals industry so as to minimize very expensive imports from Earth.

Assuming that Mars does not possess non-biogenic oil, coal, and gas resources, how far can we go towards building up a chemicals industry on feedstocks synthesized from the ingredients of the Mars air soup?

While there is a small minority group that maintains that the Earth's oil and gas reserves are not biogenic, i.e. not fossil-derived, this is a view that has a long way to go to earn respect. The mainstream view is that our petroleum, coal, shale, and much of our gas reserves are the bounty of abundant terrestrial vegetation in eons past.

If we were to find such resources on Mars, it would be quite astounding and radically revolutionize much of our geological, and even cosmological assumptions. It is a romantic notion much more unlikely than finding alien artifacts on Mars.

What is at stake? If we can even start down this road, leaving to future Martian pioneers how to advance further, we will have helped kick open the door to Mars that much wider.

But there are challenges that we must recognize. On the one hand, we have a good supply of elemental ingredients. On the other, "starting from scratch" i.e. with elemental ingredients, is not the route of chemical synthesis we are familiar with. Like many a modern Kitchen Queen or King, we are used to using "starter" pre-prepared ingredients like gravy mixes, canned soups, canned spaghetti sauce, etc. Our petrochemicals industry supplies many advanced "building block" molecules isolated from petroleum and/or coal in the refining process.

Chemical Engineering Young Turks to the Rescue

Essentially, what we must undertake on Mars is one of those "paths not taken" in the course of industrial development on Earth. Not taken, because we did not have to go that route. While some research along these lines may exist, it is a safe bet that a lot of it has not been pursued.

To prepare the way, we need qualified people to find the chemical pathways and to "engineer" ways to follow them on an industrial scale (not as laboratory curiosities.) Indeed, we may want to set up a

Mars Atmospheric Feedstocks Task Force
"Sabatier Products Unlimited"

by that, or some other name,
to pursue previously unexplored avenues.

Starting with the easy stuff first - Ammonia

In addition to fuels, one of our earliest and most essential needs will be nitrate fertilizers. It is a common misconception that on Earth, plants get all the nitrogen they need directly from the air. In fact, only certain micro-organisms, and some legumes (been family) in whose roots some of these micro-organisms live in a symbiotic relationship, are able to "fix nitrogen" directly from the air.

In our greenhouses on Mars, we will have to inoculate our soils with these special microbes and also cultivate legumes. But we can also use Mars Air to produce ammonia (NH_3) via the Haber Process and from this we can make nitrate fertilizers. Ammonia can also serve as a refrigerant.

Other logical feedstock products are NH_4OH ammonium hydroxide, and reacted with sulfur and chlorine, ammonium sulfate and ammonium chloride.

More Nitrogen products

N_2O Laughing gas is used as a mild anesthetic but can also be combusted with carbon to revert back to pure Mars Air (CO_2 + N_2) providing another fuel combination option for specialized uses.

NO Nitric Oxide can be used to make HNO_3 nitric acid for the manufacture of explosives, celluloid, dyes, nitrates and fertilizers, and as an handy laboratory reagent. Nitrogen compounds are a logical place to start.

N_2O_5 Dinitrogen Pentoxide: An inconvenient attribute

According to Jeffrey Landis, a respected NASA researcher and writer, N_2O_5 is sufficiently unstable as to be classified as an explosive. But *if* it could be stabilized somehow, (it may be naive on our part to suggest that it can) it would be very useful.

You see it is stable as a white powder throughout the entire temperature range found on Mars. *If* it could be handled safely, it could be used as air-derived shielding for Mars habitats and outposts.

The advantage? We wouldn't have to disturb the soil around the outpost to get shielding, Given all the boulders we see on Mars, and the possibility of permafrost hardening of the soil, that could be quite an advantage.

A catch is that the traditional way of preparing dinitrogen pentoxide is to react phosphorous pentoxide with nitric acid. If we could not find a direct route, then we would have to synthesize P2O5 first.

Hydrocarbon chemistry

Now it gets harder. Hydrocarbons are the most important of all chemical feedstocks. We refine these from petroleum or coal. How far can we get synthesizing basic hydrocarbon feedstocks directly from the carbon, oxygen, and hydrogen in Mars' atmosphere?

Methane CH4 is the first in a series followed by Ethane C2H6 and Propane C3H8. If we could synthesize ethane and propane, we'd have additional fuels as well as the building blocks of ethylene C2H4 (> polyethylene) & propylene C3H6 (> polypropylene -- trade names: Olefin, Herculon, etc.)

The Alcohol family begins with Methyl Alcohol CH3OH derived from Methane and Ethyl Alcohol C2H5OH derived from Ethane.

These two avenues can give us a head start by allowing pioneers to manufacture many useful products. But from here on it may get harder. Starting on this foundation, future Martians will be able to go much farther as their population increases and as their industries continue to diversify.

Growing Chemical Feedstocks on the Farm

It will be practical common sense to use biological assistance in our efforts to build a chemical industry on Mars Air resources. We will be bringing both animals (ourselves, at least) and plants to Mars and we would deserve to fail if we overlooked all the chemical byproducts these living creatures synthesize directly or indirectly.

Some instances:

- □ **Urea**, NH2CONH2, from human urine
- □ Organic **dyes**
- □ Organic **oils and lubricants** from Oliferous (oil-bearing) plants
- □ Organic **solvents**
- □ Organic **adhesives**

The list of useful plant / animal byproducts that can be used as chemical feedstocks is already lengthy and continually growing. The partnership of farm and chemical industry is a two way one.

Mining Mars Air can jump start a diversified industrial underpinning for settlement.

<MMM>

Drilling for Water on Mars

Water "on location" for drinking, bathing, growing food, and for industrial purposes.

by Peter Kokh

Up until Mars Odyssey arrived in Mars orbit, schemes for supplying water to an outpost/settlement have fallen into 3 general categories:

1. Squeeze water vapor out of the thin atmosphere. While Mars atmosphere is less than a hundredth the thickness of Earth's (at the surface) and its capacity to hold water is vastly less, there is still some water vapor in the air. In the Sabatier reactor ISRU process of air-mining for oxygen and fuels (carbon monoxide, methane) it should be feasible to produce a steady trickle of condensed water vapor as a byproduct.
2. Fetch ice from one of the caps, if the outpost is near one of them. Water Ice, known for some time to be the major constituent of the North Polar Cap, could be transported equatorward by truck, pipeline, or by enclosed, pressurized, heated neo-Lowellian canals. Not a minor undertaking, any such scheme might be part of an advanced phase.

   See MMM #62 February, 1993 page 6 " The Canals of Mars: From Self-Deception to Reality." P. Kokh
3. Taping permafrost and/or ground water

Still in the early part of its mission, the Mars Odyssey Orbiter has been detecting the tell tale signature of hydrogen. The implication is that water or water ice, not only at both poles and throughout the circumpolar areas, but just about everywhere.

The probe's gamma ray spectrometer is similar to that flown on Lunar Prospector. Its resolution is similarly coarse, about 100 km or 60 miles. This is good enough to give us a general idea, but if we want to validate a short list of premium Mars outpost locations, we will want to fly another mission with a much more powerful instrument, so that we "can land on the dime."

But the presence of frozen water or permafrost in the soils of a proposed site is still far from adequate information. What is the percentage of water content in the soil? How deep does these layers extend? How saline is it and what salts are involved?

We have become accustomed to thinking of ice and permafrost on Mars. But if this frozen resource is more than a surface phenomenon, if these deposits go down and down and ... then at some point we will encounter liquid water aquifers. Why? Because Mars has a hot iron core, smaller and less hot than Earth's but bigger and hotter than the Moon's. However cold the surface may be, at some point as one probes deeper and deeper, the temperature will start to rise, steadily. Eventually, a point will be reached where liquid water would replace ice. Can we drill to that depth? Or do such aquifers run too deep? The rate at which settlement operations, including farming and industry, can expand, hangs in the balance.

Location, Location, Location

We'll want to site our outpost, or certainly our first settlement, handy to an aquifer if possible, but not on soil so saturated that it could become unstable if we succeeded someday in warming Mars.

Water from Permafrost

There may be permafrost mining at various places on Earth, in Alaska, Canada, or Siberia. But given the abundance of streams of liquid water in most subarctic areas, it could be that no one has tried to engineer such a system. If so, that can be fixed. We can experiment with permafrost mining here on Earth.

The idea would be to come up with two or more workable systems and send an unmanned probe to a verified permafrost area to conduct field tests on location. When we send people, it would be insane to equip them with systems that have not been tested on location.

If the ice is salty

Another reason for unmanned permafrost testing on location is to determine its quality and purity. If the water ice is saline then:

1. crews will need distilling equipment to produce drinkable water
2. crews will need storage facilities to store the salts isolated in the distilling process as these will become an important resource, a treasure for both industry and agriculture

Given that the era of flowing liquid water (an ocean, rivers, lakes) has been much shorter on Mars than on Earth, there may be salt, but much less of it, i.e. in lesser concentrations. Nonetheless, salt mining could be an important pillar for diversifying Martian industries, hastening the day of manufacturing self-reliance.

Below is a chart of the major sea salts found in Earth's global ocean. If we can mine them from salt on Mars, this will add greatly to the resources we can tap in the atmosphere:

Main Salts in Earth Seawater

Cations	g/kg	Anions	g/kg
Sodium	10.76	**Chloride**	19.35
Magnesium	1.30	**Sulfate**	2.71
Calcium	0.41	**Carbonate**	0.14
Potassium	0.40	**Bromide**	0.07
Strontium	0.01	**Boric** acid	0.03

Those in **bold face** would be especially useful
-- the others should be easily found in the soil itself.

The Upshot

It is not enough to get excited about Mars Odyssey findings. We have to follow them up with a series of segue probes before we can intelligently plan a manned commitment to Mars.

<MMM>

Incorporating the "Hostel" Strategy into a Commercial Moonbase Plan

by Peter Kokh

THE LUNAR "HOSTEL": An Alternate Concept for First Beachhead and Secondary Outposts. Peter Kokh, Douglas Armstrong, Mark R. Kaehny, and Joseph Suszynski.

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- http://www.lunar-reclamation.org/hostels_paper1.htm

Intentions vs. Realities

The intention of the Artemis Project™ is to establish a "first Commercial Moonbase" as the start of uninterrupted human presence on the Moon from that point on, by leading to self sustaining resource-using settlements. The reality, however, is that just the landing of any first moonbase structure on the Moon will not likely be enough to support an uninterrupted succession of human crews.

The first landing mission is unlikely to contain the power systems that would allow "overnighting," staying through the end of the two week long lunar dayspan, past nightfall and through the ensuing two week long nightspan, before the sun rises and brings with it the energizing power of its warming rays.

Overnighting on the very first return mission would be a very mighty leap beyond the accomplishments of the Apollo era. Even the longest Apollo landing mission only stayed a few "morning hours" of one 29.5 (24 hr.) day long lunar day/night cycle.

see MMM # 88 SEP '95, p 3. Starting over on the Moon: Part I. Bursting Apollo's "Envelope", P. Kokh
Republished in MMM Classic #9
www.asi.org/adb/06/09/03/02/088/bursting-envelope.html

It will probably take several missions to build up this capacity to overnight. If we want to bring all the equipment we need to achieve this on the first mission, we will be creating an impossibly high threshold for that mission. We want to get back to the Moon as soon as possible. That means being content to bring along the "base structure" only on the first mission. That means, in fact, that for perhaps the first few missions, the "Moonbase" will be a "tended" facility only. It will take some time to transition it to a permanently manned outpost.

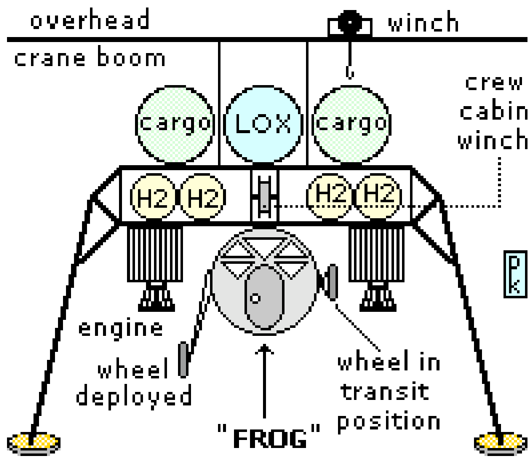
Getting through the first night, will, in comparison with the Apollo achievements, be a tremendous milestone. Getting through successive nightspans "routinely" will be another.

Many lunar enthusiasts are anxious to being lunar industry, and I count myself among them. But as the old saying goes, you must crawl before you walk. Indeed, we can do some on location (in situ) industrial demonstrations during our first dayspan set up visits. But in the light of what is at stake, it will be far more important to concentrate on building up our capacity to successfully overnight.

Enter the "hostel" concept

In our 1991 paper, we explored the hostel concept. By "hostel" we meant a structure that can function as an outpost "only when a visiting vehicle crew cab is docked with it." Our whole idea was to lower the threshold to our return to the Moon. For this, we proposed two things:

1. an outpost which would essentially be a "**big, dumb volume**" able to hold pressure, and outfitted with volume-hungry items
2. **an "amphibious" lunar lander vehicle**. Our "frog" would have an underslung crew cab, engines to either side, cargo and fuel tanks above. Upon landing, the crew cab would deploy wheels, winch itself down to the surface, and drive off to dock with the prelanded hostel outpost structure.

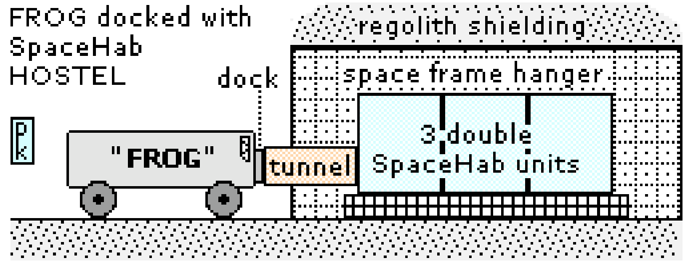


This crew cab would necessarily have to have everything needed to keep the crew alive in transit:

- □ life-support (air & water recycling, thermal controls, etc.)
- □ communications systems
- □ computing systems / work stations
- □ navigation systems
- □ galley kitchen, etc.
- □ airlock at one end
- □ docking port at the other end

Now, if this crew cab is designed in "amphibious" fashion, able to function in the ocean of space as well as on the land of the Moon, and thus able to dock with a prelanded pressurized structure, then there is no need to duplicate its systems in that structure. No, not even for redundancy. For if the systems in the lander crew cab were to fail, the crew would be stranded on the Moon, with little chance of rescue before nightfall. The lander crew cab systems have to be built to survive, and that is enough.

Until the outpost is fully outfitted and able to function on its own, dayspan and nightspan, it can accommodate visiting crews with the visiting vehicle docked. In tandem, frog and hostel will serve as a fully functional outpost. For EVA, personnel would reenter the frog, exiting the airlock at the other end.



Note the following in the above illustration which has been adapted to show the current Artemis Project™ concept for a first commercial outpost core: a triple SpaceHab unit. [Double SpaceHab units are currently being produced.]

- □ The docking tunnel is part of the Moonbase Hostel
- □ a space frame "hanger" has been built around the deployed Moonbase units, and then covered with regolith shielding by equipment deployed with SpaceHab structure and teleoperated from Earth

The reason for a shielded hanger rather than covering the outpost structure with regolith directly, is that a hanger allows for ease of expansion as well as for an unpressurized space to store fuel and air tanks and other supplies protected from cosmic rays, UV, and micro-meteorites. It would make sense to erect a generously sized hanger, with a footprint large enough to handle any and all outpost expansion foreseen as required to make it fully operational and fully nightspan worthy, without a visiting vehicle at the docking port. If shielding is applied directly, then it must be removed from those areas to which later expansion modules are to be attached. Thus the direct shielding approach sets up a hassle-loaded barrier to further expansion, thereby putting further expansion at risk of cancellation. So here is the deal:

1. tele-deploy the Moonbase main structure
2. tele-deploy hanger and shielding
3. send first crew in "frog" and *open up shop!*

Division of Labor between Frog & Hostel

The "Frog" contributed functions the visiting crew cab must have anyway just for the journey from Earth to the Moon:

- □ Communications Center
- □ Navigation Systems, Computer Bank
- □ Air quality and ventilation
- □ Thermal management controls
- □ Water recycling / treatment
- □ Toilet & Shower
- □ Fresh Food locker
- □ Galley: meal prep, scrap disposal
- □ First aid & trauma cabinet
- □ Cab windows, both ends
- □ In place exercise center
- □ in transit entertainment console
- □ Limited tape/disk collection

Capacities incorporated in early frogs, and gradually switched to the hostel structure:

- □ EVA airlock for Moonwalk sorties
- □ Laundry facility
- □ Isolation berth(s)
- □ Wet/dry compact workstation

- ☐ Moon rock sample analysis
- ☐ Moon sample experiment lab
- ☐ Electrolysis equipment for LH2, LO2
- ☐ Fuel Cells for use when uncoupled

Functions Contributed by the "Hostel"

At first, the triple stack SpaceHab Moonbase would house space-intensive functions:

- ☐ "Bedrooms" with personal computer
- ☐ Lounge-Chapel-Dining "ward room"
- ☐ More ample exercise room
- ☐ Growing Library (multimedia)
- ☐ Office
- ☐ Dry space-needing workstations
- ☐ Dry storage for samples, sorting, etc.
- ☐ Panoramic visual access to the outside (if not in the original landing stack, then a priority for early added modules)

With each visiting frog, more equipment would be brought in to gradually develop operational autonomy for the outpost (i.e. without docked frog). As the hostel becomes better equipped, each frog mission can

- ☐ Main (solar power) generation equipment
- ☐ Electrolysis equipment for LH2, LO2 using waste water as a feed stock
- ☐ Fuel Cells to turn LH2 & LO2 into power and fresh water during nightspan
- ☐ Toilet, shower, laundry facilities
- ☐ Unpressurized rover
- ☐ Expanded medical facility

As successive frogs need to arrive ever less "loaded," they can bring along more and more cargo. Finally, the last "frog" mission can leave the frog on the Moon to serve as the outpost's pressurized lunar exploration / field trip rover / coach / campmobile. When its crew needs to be replaced, it can go home on the next visiting vehicle. The "frog" would become a "toad" in effect, giving up its amphibious spacefaring capacity for a wholly ground-based future.

Design Objectives of the 1991 Hostel Study

In writing our paper for ISDC '91, our ultimate purpose was to define the easiest, lowest possible threshold for returning to the Moon with a shelter that could gradually be developed into a fully autonomous outpost, capable of supporting crews throughout the lunar dayspan-nightspan cycle (the "sunth") as a beachhead on the Moon that could grow in time to become a resource-using industrial settlement for people choosing to make the Moon their homes.

It is not our purpose here to suggest an alternative to the current SpaceHab stack design for the initial Artemis Moonbase™. Rather we want to suggest a better way to carry out that or any other mission similar in scope, a better way to insure that a first "moonbase" is not another dead end stunt, only with a commercial twist.

From the Apollo moonwalk "picnics" to setting up a permanent cabin or camp on the Moon is a big step. It requires more than setting down *a* pressurized structure. We hope this essay encourages reexamination of these mission plans, integrating these proposed improvements. **<MMM>**

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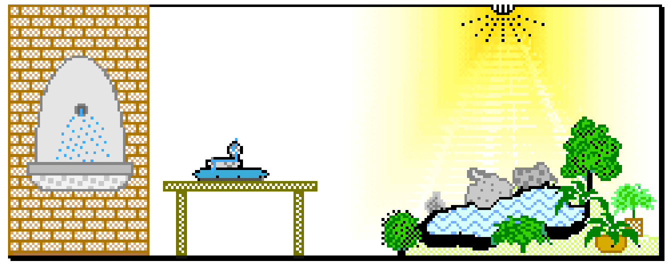


Water Features Calm Pioneer Homesteads

Whether they are hung on a wall, placed on a table, or worked into interior garden spaces, water features such as fountains, waterfalls, and ponds could bring soothing sounds, visual interest, and opportunities for color to spartan pioneer habitats. More, they will be evidence of the "hydrosphere" that underlies every biosphere. More, *below*.

N Nitrogen N_2

Symbol **N**
Atomic Number **7**
Atomic Weight **14**
Molecular Gas N_2
Molecular Weight **28**

Nitrogen and the Moon's Future: Conservative use of this scarce critical element is key to "limits to growth" of Lunar Settlements

by Peter Kokh

Cosmically speaking, Nitrogen is one of the universe's more abundant elements. Earth's atmosphere is 79% oxygen. There is three times as much (by weight, not by percentage) on Venus. Mars' thin atmosphere is 3% nitrogen. Titan's thick atmosphere has more Nitrogen than that of Earth. There is plenty in the deep atmospheres of the gas giants.

All that does little good on the Moon. Unlike the Earth, the Moon formed "hot", condensing out of the hot plasma debris of a major crash between the proto-Earth and another early planet-in-formation. In the heat from the impact, almost all "volatile" elements, those with relatively low boiling points, were driven off into the surrounding space, never to be recovered. When the Moon coalesced from this debris, it formed "dry" - no water, no free gasses. Any carbonates were disassociated and the carbon driven off. Only oxygen, which forms tight stable bonds with most metals, was retained.

What nitrogen is found on the Moon is from two *external sources*, one known, the other surmised:

- **Known regolith reserves:** nitrogen atoms in the thin but incessant solar wind have become affixed to the fine particles in the dusty topsoil blanket that covers the Moon: the regolith. This resource is primarily in the top meter or so at an average of 82 parts per million.

- **Possible polar ice reserves:** if the suspected polar ices "found" by Lunar Prospector are confirmed by a "ground truth" probe, it is almost certain that they are derived from cold trapped vapors released when comet fragments have impacted the Moon. Comets consist not only of water ice, but of nitrogen oxide and carbon oxide ices as well, in a mixture dubbed "clathrate." One of the primary goals of a polar ground truth probe would be to qualify and quantify this mixed ice bonanza. Someday there may be refineries at the poles producing CH_4 methane and NH_3 ammonia as well as water, for shipment by truck, rail, or pipeline to industrializing settlements in other areas of the Moon.
- **Off-Moon sources:** import of nitrogen in the form of ammonia, from comets and asteroids if and when such resources can be economically developed to provide steady "pipeline" supplies.

The Bottom Line:

On Earth, an 1800 square foot home with 9 ft. ceilings, at sea level, contains a half ton of nitrogen. *To provide that much on the Moon would require gas scavenging an average of 6,100 tons of regolith at 100% efficiency*. Anything we can do to cut that burden will allow settlement to grow more quickly.

Of all the elements essential for life (oxygen, hydrogen, carbon, nitrogen) it is nitrogen that is in shortest supply on the Moon in comparison to the amounts of it we are accustomed to using -- simply as the buffer gas for our oxygen-based breathable air. As settlements grow, it will not be shortages of hydrogen (water) or carbon that put on the brakes. It will be nitrogen that becomes the pinch point.

The Case for Reduced Air Pressure

One way to "go easy on the nitrogen" would be to simply maintain and regulate low ceiling heights in lunar settlements, not just in private quarters, but also in public places. Less volume of air means less tonnage of nitrogen. Such a Spartan constraint would not exactly foster high morale, especially over the long haul. But without other ways to conserve, we may well be facing such a gloomy prospect .

What else can we do? Reduce the air pressure in habitat areas. Additional savings could come from reducing the relative abundance of nitrogen in the reduced atmosphere, keeping the partial pressure of oxygen closer to what we are accustomed.

Readers who frequent the Artemis Discuss List will no doubt be exasperated by this suggestion.

> "Oh no! We've been through all this before! It can't be done, and NASA uses Earth normal pressures and mixtures in space. A discussion on the Artemis-list hashed this out in considerable detail. It is not true that we can live in lower air pressure. The atmospheric pressure at 7,500 feet is *not significantly less* that at sea level."

With all due respect to those who took part in this discussion, we believe *all* the premises behind these assertions are flawed and inaccurate. It is vital for those of us who have faith in a bright future for lunar settlement to seek out a second opinion.

The Facts:

A table on the reduction of air pressure with increasing altitude is available online at:

http://www.cleandryair.com/AltitudePressure.htm

Sea level air pressure is the equivalent of a column of Mercury 760 mm high (30 inches). Here is what the table shows for some higher altitudes:

Altitude	**Pressure**	**%** (1 ATM = 100%)
7,000 ft.	586.7	77%
(**Mexico City**'s 22 million live at 7,600 ft.)		
8,000 ft.	564.6	74%
(**Bogota**'s 7 million live at 8,600 ft)		
(**Nairobi**'s 2 million live at 8,800 ft)		
9,000 ft	543.3	71.5%
(**Quito**'s 1.5 million live at 9,500 ft)		
10,000 ft	522.7	69%
(**Cuzco**'s 300,000 live at 10,600 ft)		
(**La Paz**, Bolivia's 1.5 million live at 11,800 ft)		
Millions have been on top of Pike's Peak, 14,000 ft		
15,000 ft	429.0	56.6%

Can thirty five million people be wrong? It is quite clear from these figures and the interposed list of high altitude cities where millions live, that the Artemis-list conclusions are *prima facie* in error.

> "Nevertheless, a very large portion of the population has difficulty adjusting. Also note the life spans of the places you've listed."

It was noted during the Mexico City Olympics (1968) that those athletes who live at lower altitudes had enormous difficulties competing, *unless they had exercised the foresight to come to Mexico City a week or two early to acclimatize themselves*. Those who did so did well.

And life spans relate to medical care.

The argument from the experience of some people who have difficulty adjusting is irrelevant. It cannot be expected that everyone would be able to adjust to life on the Moon or Mars, and there are a lot of reasons for that: claustrophobia, black sky blues, loss of open-air living, lower gravity, air pressure. We know all that, and have always known it.

Prescreened settlers will come from the ranks of those who tolerate all these conditions well.

All that is necessary for settlements to thrive is that there are enough who can adjust.

Those who argue from the admitted fact that some cannot adjust ignore the rules of simple logic.

"Some people do not make good parents, therefore parenting is unwise."

Same type of invalid argument.

There are a great many skeptics about the rationality of our faith that humankind can sow itself on other shores beyond Earth's.

"We were evolved at 1 ATM and 1 G and it is not possible for us to be *pre*-adjusted to tolerate anything less!"

If we are to give in to them on the atmospheric pressure question, then we might as well give in to them on the gravity issue. *But let's not.* Life is about adaptation, not only over many, many generations, by evolution, but within the experience of individual lifetimes. Humans originating in East Africa have dared to step out of "their niche" over and over again to the point where we now thrive from the polar arctic to the high altiplano of Lake Titicaca and La Paz, Bolivia.

Why Air Pressure is a Critical Issue

The suggestion to use reduced air pressure in our outposts and settlements on the Moon and Mars is not lightly made. It is simple physics that

the higher the inside/outside pressure difference,
the greater the propensity to leak air,
and the greater the likelihood of seal failure.

And this likelihood increases on a geometric scale. Choosing a reduced air pressure is then first of all a matter of common sense safety. The Moon and Mars are very unforgiving places. If we respect the dangers and the risks, our chances of successful transplantation to either world will be that much greater. Not to do so based on assumptions born out of history or habit or respect could invite failure. We have a saying that "it is easier to find forgiveness than to get permission." That approach works with people and institutions, but not with Nature.

Extra incentives for Lower Lunar Air Pressure

On the Moon we have three additional incentives to use reduced air pressure in our habitats:

1. The more our habitats leak, the more likely we will end up "polluting" the lunar vacuum to the point that it ceases to be a major industrial and scientific resource.
2. The more our habitats leak, the more nitrogen we will lose (nitrogen is enormously more difficult to come by on the Moon than oxygen) and the sooner we'll reach the Moon's "carrying capacity"
3. The less nitrogen we use as a buffer gas in our habitat atmospheres, the less expensive it will be to provide higher ceilings in public spaces as a welcome relief to eye strain and cabin fever.

Reducing Nitrogen Richness as well

One of the cases made against reduced air pressure is that "some" people have difficulty adjusting to it. Aside from the irrelevance of this argument, the difficulty cited comes entirely from the proportional reduction in the amount of oxygen. But who says we have to keep the same gas ratio we have on Earth (79& nitrogen, 21% oxygen)? What if we were to keep the oxygen partial pressure at comfortable levels and achieve all of the reduction in total pressure by reducing the amount of nitrogen gas used as a buffer? The following table assumes just that:

Mix (N/O) (N2/O2)	Pressure (%1ATM)	N2 Savings (tonnage)
75/25	84%	20%
70/30	70%	38%
65/35	60%	51%
60/40	52.5%	60%

But, but ... fire risk and oxygen poisoning

Most of us know the dire consequences to the Apollo 1 crew of using an atmosphere of 100% oxygen. One spark and they were toast. There is, however, an enormous difference between 0% nitrogen and say 60%. But let's humor those concerned about fire risk and admit, for the sake of discussion that a 60/40 nitrogen/oxygen ratio makes combustibles more likely to ignite.

On Earth we are surrounded by combustibles. For one thing we use a lot of wood, a lot of plastics. On the Moon, however, items made of wood and other organics, natural or synthetic, would be very very pricey. We will need to reserve all the nitrogen, hydrogen, and carbon we can harvest for biosphere biomass and food production cycles.

On the Moon we will rely much more heavily on inorganic substitutes: metal alloys, ceramics and cast basalt, glass and glass composites. The typical lunar home, office, school, or other kind of space will have very little in the way of combustible materials *outside of clothing, bed sheets, towels and the like*. Even the casings for electrical wiring are more likely to be of woven fiberglass than Romex plastic. Electrical fires will be much less common than on Earth.

All this is good, because fire is far more likely to be fatal on the Moon than on Earth, You can't just open a window to let out the smoke. You can't just open a door and escape outside. Future Mars settlers will be under no such materials rationing restrictions. The sad twist is that the incidence of fire and fire fatalities on Mars is likely to be much greater.

Some fear oxygen poisoning in an oxygen enriched atmospheric mix. But this phenomenon only occurs when the oxygen mixture is near 100%. We are proposing 42%.

Don't sea level crops need sea level nitrogen?

On the Moon we are surely going to want to grow more than coffee, tea and other crops usually associated with high altitude. The altiplano of Peru and Bolivia are not exactly gardens of Eden or breadbaskets to the world! Yes, but!

It is true that this high altitude area on Earth is no green paradise. Is that the result of reduced nitrogen? If that is the conclusion you want to reach, it will be the most plausible answer. But in fact, the altiplano is relatively infertile for climate reasons that have nothing to do with the reduction in nitrogen partial pressures. The are is colder because it is higher up. An because it is on the lee side of the Andes, it is drier, and windier. Also, much more UV gets through the thinner air.

Dry, cold, windy -- not exactly the conditions that make for rich, fertile soil. But to conclude from this fact that reducing nitrogen partial pressures will mean cold, dry, windier lunar settlement interiors with poor soil is absurd.

In fact, in response to the quickly rising population of the area, especially around La Paz, there has been much agricultural research of late and the results are amazing.

- http://www.idrc.ca/books/reports/09highla.html
  - □ onions, radishes, beets, and carrots and lettuce at 4,200 meters (13,839 ft.)
  - □ potatoes: three harvests a year in greenhouses
- http://www.eco.utexas.edu/graduate/Blubaugh/papers/ISEEpaper.htm
  - □ sustainable development in Bolivia's Altiplano

If you do a web search for altiplano crops or altiplano farming, you will find much more evidence to support the conclusion that high altitude / lower nitrogen partial pressures do not mean having to live on coffee alone. How can this be?

Simple. Most plants do not get their nitrogen directly from the air. They absorb nitrogen from the nitrates in the soil, put there by microorganisms that *can fix nitrogen directly* from the air. Some plants, like legumes (bean family) live in symbiotic association with such microorganisms and planting them enriches the nitrate content of the soil. Bottom Line: Nitrogen-fixing microorganisms thrive at all virtual altitudes discussed. "Sea level plants" do not require "sea level nitrogen."

NASA Studies

What about NASA studies? The assertion is that NASA has studied all of these questions exhaustively and come to the conclusion that sea level air pressure and mixture is best. Why else would both the former Mir and the International Space Station use 14.7 pounds of air pressure?

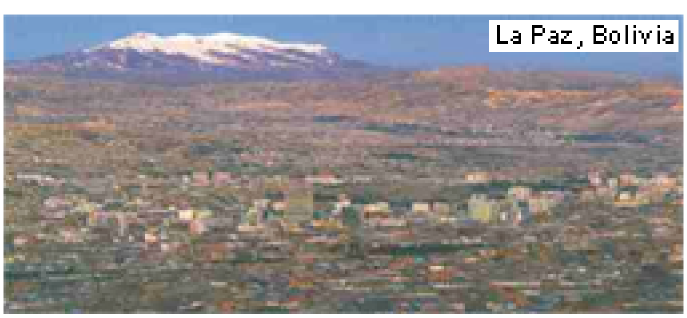
NASA has done many great things. But there are good reasons to believe that it is *highly unlikely* that research on this question has been exhaustive.

- NASA has never looked that far ahead to the point that human expansion might be limited by the availability of nitrogen. NASA's lunar outpost studies have focused on small crew installations with individuals serving short terms of duty. For NASA to spend research dollars on "far future" options would be wasteful in that light.
- NASA has wisely chosen standard sea level air pressures and mixtures *because man-hour time in space is prohibitively expensive,* too much so to waste any of it on "adjustment time." Once we start talking about settlements, where people have come to spend the rest of their lives, a short period of adjustment difficulty (for which all volunteers will already have been pretested before leaving Earth) is hardly a major concern.

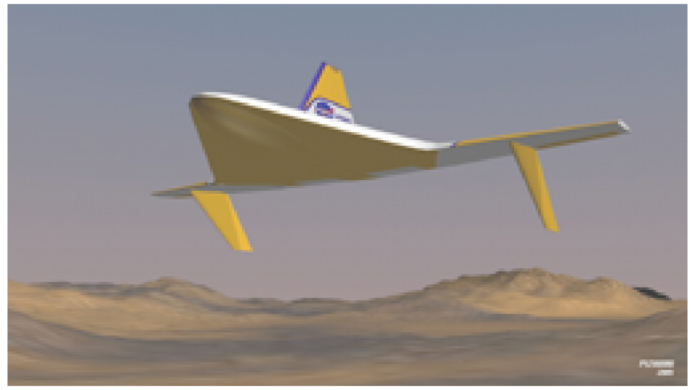
But is it not brash and rash and disrespectful to NASA to request fresh research? In science, it is standard practice to check and recheck results of others. In medicine it is standard practice to request second opinions. If NASA is offended, then it has put itself on some sacrosanct pedestal above other scientists and researchers. *No disrespect is intended.*

There is simply too much at stake on this question to settle for results of past studies there is every reason to believe have not been exhaustive or free from preconceptions that tend to color results. Instead, let's put all prior conclusions on hold, and mindful of the nontrivial consequences, examine the facts afresh with an open mind.

We owe our dreams that much! **<MMM>**



Mars Aviation Task Force



Postscripts to last month's article MMM #153

From Paul Swift (1) and Peter Kokh (2)

(1) **Paul Swift's 2000 Paper** "Aviation on Mars: Five Concepts for Airborn Access" is online at:

http://www.css.ca/marsaviation.htm

(2) **Severe Cold** is yet another challenge to be overcome in the realization of Crewed flight on Mars:. Recall that the recent rescue of a doctor with breast cancer from the South Pole Antarctic Station was problematic because of the danger of the airplane's fuel jelling in the tanks at the temperature of -60 °F. It gets regularly much colder than that on Mars.

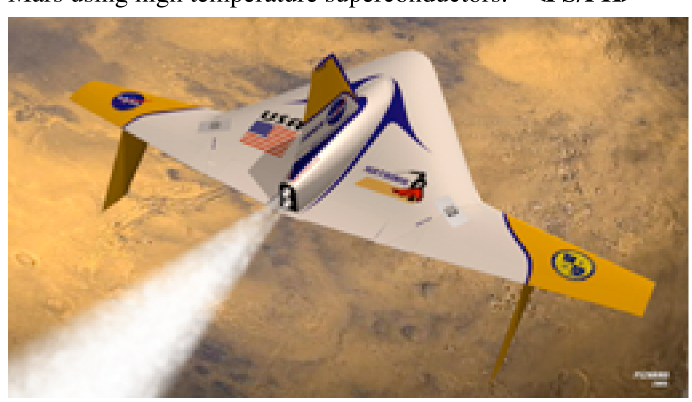
How do we keep fuel from jelling?
How do we keep lubricants lubricating?

The first question may be easier. If we are using fuels derived from Mars' atmosphere, such as methane and oxygen, they will be pressurized gasses rather than liquids. There is no danger of it getting cold enough anywhere, anytime on Mars to liquify or freeze either of these gasses.

- methane liquifies below - 161.5 °C (-258.7 °F)
- oxygen liquifies below -183.0 °C (-297.4 °F)

Lubricants are another matter. They are usually semi-viscous liquids or jells and they will harden at very low temperatures. Silicone-based (not hydrocarbon-based) formulations are stable to lower as well as higher temperatures, but would still limit flying operations. This is a problem that must be solved for ground transportation as well.

Ultra-fine graphite powder? Heating the lubricants and bearings? Magnetic bearings? The latter may be ideal for Mars using high temperature superconductors. - **<PS/PK>**



Therapeutic Indoor Recycling Water Features

by Peter Kokh

Thanks to strong marketing by suppliers for garden pools and water features, both indoor and outdoor, these delights are finding their way into more and more gardens and homes each year. One can buy fully assembled predesigned units in a bewildering array of sizes and styles, or buy key parts and create one's own. Imagination, not cost, is the only limit.

Indoor "water features" would seem to be just what the doctor ordered to make lunar homesteads inviting retreats. The reasons are that they:

- use only recirculating water reserves
- require only lightweight imported pumps, hoses
- can use basins made of many lunar materials
- are an opportunity to "domesticate" moon rocks
- are an ideal setting for plants
- can be combined with fish ponds
- offer several ways to add color
- provide a treat for four of the five senses

Recirculating Water

The water used in these water features recirculates over and over. One must make up for evaporation, of course, but evaporated water is not lost to the biosphere as it can be recovered by dehumidifiers. It is essential that the outpost or settlement have more than marginal reserves of water as a matter of safety and security. But why not put such reserves "to work" in ways that improve overall morale? (see MMM #67, July '93, p. 6. "Reservoirs")

Imported Pumps

These water features use small pumps that are relatively light weight, plus hoses and clamps. It can be argued that the intangible benefits of having water features in homes, home gardens, and public common spaces is great enough to justify their import -- after all, the vast bulk of the weight (basin, water, and sundry adornments) can all be made locally.

Made on Luna Basins

Basins, pools and step pools need to be impervious to water and are commonly made of inorganic materials. On the Moon we can make such items from glassified regolith, glass composite, cast basalt, various metal alloys, glass-sulfur composites, and concrete. The choices are quite wide and will support a wide variety of sizes and variation in design.

Incorporating Moonrocks

Water feature designers often incorporate rocks in their creations. After all, in nature, rocks are invariably associated with waterfalls and rapids. We won't find "river rock" anywhere on the Moon, of course, but we should be able to make interesting arrangements using larger moonrocks and breccia. As an alternative, we could "make" rocks by casting basalt or concrete in various shapes. In the first path, we find one more way to "domesticate" moon-rocks and thereby make the surface that much less alien to the eye.

Working in Foliage

Again, in Nature, foliage is commonly more dense and rich in proximity to water. We can make our house plants look more natural clustered around a water feature. With a little ingenuity and extra plumbing, we might even train the water feature to meet the watering needs of the plants.

Integrating Fish Ponds

In larger size fountain pools and waterfall basins, we can raise a variety of common aquarium fish species. Fish add surplus motion and color, and reinforce bonds with nature that would weaken if we had only plants to enjoy.

Avenues for Color

Integrating a water feature into the home or home garden, provides several opportunities to add extra color for the eye to feast upon:

- □ moon rocks in direct contact with water or even just splashes of water, may tend to take on rusty patinas, to the extent of their iron content. Rust will be a warm tone that will provide welcome contrast to background gray tones of structural concrete, cast basalt, glass composite, or metal.
- □ the many greens of foliage. Plants go well with rust tones, by the way. Think terra cotta pots!
- □ flowers and blossoms
- □ colorful fish

Treats for Four of the Five Senses

The reader is welcome to try to identify ways in which water features provide a taste treat for the tongue. We didn't try. As to the other four senses:

• **Eyes:** The designs and shapes of fountains and waterfalls can be designed are limited only by the imagination. They can be rustic or crisply geometric, incorporating many textures. Amateur-friendly, they are also inviting to artists as well. Spot lighting can be used and/or underwater lighting. Plus colors!

• **Ears:** Soothing "white noise" that varies with flow and design.

• **Nose:** That fresh "after-the-rain" smell in the air.

• **Touch:** Textures of the different surfaces can vary from ultra smooth to quite coarse or even sharp. A randomizer added in to the ventilation system, could waft gentle fresh breezes around the surroundings.

Settlers need ample morale boosting perks. Water features will be among them. **<MMM>**

MMM #155 - MAY 2002

Opening of Space Tourist is for real. Where do we go from here?

Opinion Piece by Peter Kokh

Bringing down the Price of Space Tourism

$20 million smackers is a lot to pay for even a "once in a lifetime" experience. Yet there are indeed enough people out there with that kind of money, and, that kind of free time, to guarantee that even at that price, not too many empty Soyuz seats will go unfilled. It would seem that the Russians need not worry about pressure to reduce prices anytime soon. So how do we get off this dime?

A week-long visit to the International Space Station is, when you think of it, a rather ambitious level at which to jump start space tourism. In fact, that is not how we thought it would start. The X-Prize program, which has yet to produce one viable spacecraft, was supposed to open the door to suborbital hops, the kind of threshold crossing pioneered by Mercury capsule astronauts Alan Shephard and Gus Grissom in 1961, and by a X-15 pilot Joe Walker twice in 1963. To be officially considered having reached the edge of space, all one has to do is reach an altitude of 100 kilometers, 62 miles, however brief the stay (International Aeronautics Federation.)

Things haven't started that way. What the X-Prize incentive has failed (so far) to produce, however, the dire economic circumstances of the Russian Republic have. Necessity is the mother of invention, and the Russians can produce vehicles for quickie sorties to gates of space.

Not only does Nature abhor a vacuum, so does Economics. Market demand, awakened by Tito's feat, is there in undeniable force. That someone would find a way to serve that market was inevitable.

From the bottom of the Ladder back to the Top

Starting at the top of the ladder, as illogical as this development would seem to be, has served its purpose in whetting public appetite for first hand experience of "Space." Now, while the rich-set flights continue, the momentum will shift to the more humble threshold of space ventures.

Rung One: Meanwhile, not everyone has been content to wait patiently. A growing number of civilians have experienced a half minute or so of weightlessness aboard the KC-135A "Vomit Comet" used by NASA to conduct zero-gravity testing and experiments. Now, for $5,400, anyone can get a ride on the KC135A's commercialized Russian counter-part, the Ilyushin-76. Space Adventures, Ltd., offers the 2-hour flight from Star City, the Russian cosmonaut training center outside Moscow. Passengers experience a half minute of free fall during each of about 10 dives. As the plane reaches full throttle headed up at a 50° angle, the engines are cut and it coasts to the top of its aerial roller coaster run. Weight return as air friction begins to slow the plane on its descent.

Rung Two: longer and higher flights. We could start to see Intercontinental flights, and that would certainly jump start demand for hypersonic airliners, bringing the price down to somewhat above that of a transAtlantic flight on the Concorde.

Rung Three: up into orbit and back to the starting point (a distinct logistical advantage over Intercontinental flights). Around the world once in 90 minutes, repeating the first ever space flight of Yuri Gagarin in 1961. These tourists will coast much higher up, over a hundred miles, and see much more of the beautiful Earth below. Yet this remains a modest endeavor, with minimum hygiene and food or drink provisions, no need at all for the recreational diversions of much longer flights. We can expect to see "Yuri Flights" by the end of this decade.

Opportunities aboard a transformed Space Station

By that time, it is not clear in our crystal ball that working vacations for guest astronauts aboard the Space Station will still be going on. A lot depends on if and how the Space Station grows and evolves along with its support infrastructure. That is another topic. Hopefully, U.S. cutbacks will lead to other nations and commercial enterprises stepping up to the plate to fill the vacancy. A less dominating position for NASA might provide a more favorable climate for the emergence of an independent multinational Space Station Port Authority, tasked, beyond politics, with growing the station to become "all it can be" -- which is a lot.

How big is the market for this? It would seem inexhaustible. Note:

- the around-the-world cruise market has proved quite sustainable at about the same price range
- a surprisingly large number of people, at least in North America, could pay for the ticket with a second mortgage on their homes (unfortunately, that doesn't include the writer, nor perhaps, the majority of MMM readers.)

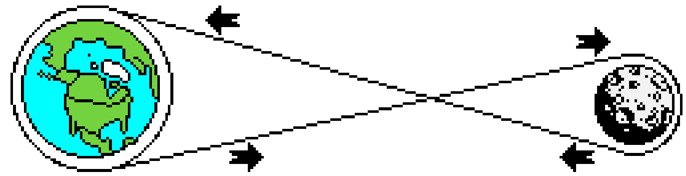
Beyond simple orbits - Orbitels & Moon Looping

The next step is providing "places to go," a "cruise ship stop" or two in orbit. Bigelow Aerospace and others are already researching and planning for the time when the market makes dedicated orbital tourist facilities inevitable. Involved are two things:

1. Larger space than a shuttle cabin provides - space to support additional activities: hygiene, exercise, dining, socializing, and more
2. More provisions than are needed to support suborbital and one-orbit flights of a few hours.

Many will be surprised to hear that an orbital hotel may not be the only, or even the cheapest way to realize this quantum leap in support and services.

For virtually the same amount of money as a week long stay in the "Cloud Nine" or "Terra Heights" resort complexes, one could transfer in orbit to a larger freshly refueled craft, and rocket off on a six-day loop the Moon trip on much the same trajectory as that of the suspense filled flight of Apollo 13, but hopefully without the drama.



The amount of provisions needed for the Moon loop would be about the same, with the spaciousness of the cabin facilities fuel-conservingly less, than for an orbitel week long stay. What we are predicting is startling, perhaps. You will be able to loop the Moon without landing, cruising low over the farside terrain, at about the same time in history as the first orbitels and space resorts open for business!

There is one fly in that ointment - space sickness. The larger orbitels will probably be much better able to cope with guest indisposition than will tight-quartered Earth-Moon coastal cruisers. One possibility is that the Moonliners will require their passengers to have previous zero-g experience, in order to filter out those likely to weather the experience badly. An old sailors' poem which goes "Sail, Gale, Pale, Rail." Well, there won't be a handy rail on those early Moon-loopers!

We wrote a two page article on "Lunar Overflight Tours" in MMM # 21, December 1988. Find it online at:

http://www.asi.org/adb/06/09/03/02/021/
lunar_overflight.html

So when do we get to go?

The answer to that "bottom line" question depends upon a number of things:

- the success of the X-Prize Program to produce not only a winner, but a design that can be commercialized to provide rides to the edge of space, 100 miles up.
- the entry of competitors who will try to do that excursion "one-better"
- the general state of the national and global economies
- the construction of commercial orbital facilities unconnected with the ISS
- and any number of unpredictables

Despite the unknowns which are always present in any forecast of future developments, the long anticipated dawn of "real space tourism" would seem to be upon us. By the end of the decade, the number of actual space tourists should be over a hundred, perhaps well over that figure. Beginnings are the hardest. Once the threshold is crossed and experience on the other side grows, momentum and crescendo would seem likely. *Engage!* **<PK>**

Abstracts of Papers Presented at the 2002 Space & Robotics Conference by members of the Oregon L5 Society Lunar Base Research Team

Gecko-Tech in Planetary Exploration and Base Operations

http://www.OregonL5.org/docs/sr2002a.pdf

Thomas L. Billings, Robert D. McGown,
Cheryl Lynn York, Bryce Walden

Abstract

Geckos can walk straight up walls and across ceilings. Dr. Kellar Autumn and colleagues have discovered their secret: gecko feet have hundreds of thousands of hair-like "setae" with hundreds of submicroscopic pads ("spatulae") at each seta tip, which appear to cling by van der Waals forces to almost any surface. Unlike suction or traditional adhesives, this adhesion works under conditions of vacuum and particulate contamination, making it potentially ideal for use on the Moon and Mars. It is also remarkably strong (10 N per 100 mm2 in vivo), yet quickly and easily released.

Lavatube caves, on any world, can be one of the most extreme terrains in which to operate. The caves consist of raw, unweathered lava. Cave floors covered with random piles of large boulder "breakdown" make exploration difficult for humans or robots. The ability to traverse lavatube walls and ceilings would make such exploration much easier; this could be accomplished by using gecko-derived biomimetic technology. "Gecko-Tech" can greatly enhance efficiency and effectiveness of cave exploration and development. These technologies can also find many other uses outside of lavatubes.

Gecko-footed robots could climb to the lavatube roof and emplace permanent anchors for suspension of utilities, transportation, or even entire lunar bases. Tethers tipped with gecko-tech pads can extend the reach of robots and humans. Humans wearing a flexible skintight spacesuit with gecko-tech pads could climb over large rocks on lavatube floors, or up lava walls. Such a garment would be useful to climb the red cliffs of Mars or to perform maintenance work on slippery habitats.

Gecko-tech will increase the capabilities of emergency and rescue operations. It will enable new forms of sport and recreation.

Gecko-tech enhancements of human and robot mobility expand the range over which humans and robots can work, becoming an effective productivity multiplier.

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Lavatube Entrance Amelioration on the Moon and Mars

http://www.OregonL5.org/docs/sr2002b.pdf

Robert D. McGown, Cheryl Lynn York,
Thomas L. Billings, Bryce Walden

Abstract

To explore and utilize lavatube caverns, a negotiable entrance is vital. Lavatube entrance amelioration includes clearing debris, establishing a transportation right-of-way, and preparing for and installing various access aids. There are four main types of entrances to lavatube caves: a "rille entrance," a "skylight," a "hornito," and an engineered, artificial skylight.

A rille entrance should be easiest to improve. In rare cases it may be possible to simply walk or drive into the lavatube. More likely, the rille entrance will be choked by initial rille collapse and eons of weathering. A mucker and cable assembly used to clear the entrance might become a cable car. Later, a suspended road may be built.

A skylight forms when a small portion of the cave

ceiling collapses. The skylight entrance is prone to further collapse. Given their great age, unstable areas will probably have collapsed already. Beneath the skylight, there is most likely a chaotic pile of collapse debris ("breakdown"), covered with regolith. Dangerous slopes of regolith lead into the hole. Survey and stabilization are the first steps of entrance amelioration. Mechanical aides from nets and ladders to A-frame pulleys and small elevators can then be emplaced. Later development could include large freight elevators up to a skylight-spanning "Maxivator" suitable for lowering entire ships into the lavatube shelter.

Hornitos occur where temporary blockage within the active lavatube causes molten lava to burst out to the surface, leaving a surface cone of solid basalt with a central hole leading to the cave. There may only be minor debris below this hole. A hornito provides a strong lip and solid foundation for devices to lower material and people into the cave.

Where a cave lacks a handy entrance, an artificial skylight could be created. The edges of the hole would be engineered, and the roof is not necessarily weak in its vicinity. Utility holes of various sizes could be drilled directly. Larger holes could be created by direct blasting, or precision blasting to result in a removable plug.

The improvement of lavatube entrances will require a range of engineering solutions. Since lavatubes on the Moon or Mars are expected to be vast, the effort of entrance amelioration is small relative to the sheltered space it makes available. The cost is low compared to the payoff.

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Moon Lighting: Illumination for Lunar Base Construction and Operations

Robert D. McGown, Thomas L. Billings,
Bryce Walden, Cheryl Lynn York

Abstract - www.OregonL5.org/docs/sr2002c.pdf

Lunar bases will need lighting for exploration, construction, mining, industry, life support, operations, and maintenance. In many respects, lighting on the Moon will involve adaptations of familiar methods. Efficiency, robustness, and serviceability will be required.

During the lunar day, sunlight is available using heliostats, lenses and light tubes. Some of these items can be used for distribution of artificial light as well. Illumination may be augmented by using transparent, translucent, light-colored or reflective walls and panels.

Moon lighting presents special challenges, such as dust amelioration, heat management, and lavatube illumination. Spectrum manipulation can promote or inhibit living organisms, as desired.

Using lunar resources to manufacture lighting equipment will save money over Earth sourcing, so designs should be compatible with lunar sourced components as these become available.

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"As long as we're here...": Secondary Profit Generators for Moon and Mars Bases

Bryce Walden, Cheryl Lynn York,
Thomas L. Billings, and Robert D. McGown

Abstract - www.OregonL5.org/docs/sr2002d.pdf

Lunar and Mars base planners concentrate on one or two economic drivers to justify a base. This is like the "killer app" in the computer world, the single indispensable application that justifies the computer purchase. "Secondary profit generators," numerous economic activities that make a complex lunar or Mars base work, have received less attention.

Trade with Earth is a special case. Due to Earth's deep gravity well, transportation costs are far from reciprocal. Earth industry produces vital items unavailable elsewhere; however, Earth's large population represents a huge market for offworld products.

Space commerce among bases on the Moon, Mars, and elsewhere in space brings opportunities in transportation, sales, legal services, and trade in minerals and volatiles, to name a few.

As bases specialize, an interbase economy will develop. Bases can specialize in power production or construction, for example. Precious volatiles could be traded, as long as they remain onworld.

Intrabase economy, or commerce within a single base, opens up a range of small business possibilities including repair shops, laundry, professional services, and others.

The more secondary profit generators a base can develop, the stronger and more resilient the base economy will be. Settlements initiated as "company towns" will transition to diversified economies.

Ultimately, the aggregate of secondary profit generators could dominate base balance sheets and do away with the need for a single economic driver to make a base a viable, going concern.

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Lunar "West Pole" Prime Meridian

Bryce Walden, Robert D. McGown,
Cheryl Lynn York, Thomas L. Billings

Abstract - www.OregonL5.org/docs/sr2002e.pdf

We impose coordinate systems on planetary surfaces to define locations, compute distances and areas mathematically, and give us a control grid for mapping. The poles, equator, and parallels of latitude are defined by the planet's intrinsic property of rotation, but placement of the Prime Meridian of longitude is arbitrary. Proper placement and use of the Prime Meridian can make the coordinate system easy and intuitive, or difficult and confusing. Current systems in use for the Moon (more than one are used) are awkward and out of date. We propose the Prime Meridian bisect a prominent feature close to the Moon's "West Pole": Mare Orientale (20°S, 95°W); and, that longitude increase from 0° to 360° in the direction of rotation. We call this the "Lunar West Pole Prime Meridian" system.

Today's "Mean Earth / Polar Axis" system dates from 1775 when mariners used the Moon to find longitude at sea. The mean sub-Earth point, in the center of the nearside, defines the Prime Meridian. Meridians are referenced in degrees east and west, or + and –, from this point. No significant lunar feature marks this Prime Meridian. This system is still used, with one major change: "east" and "west" were switched by international agreement in 1961. Earth's Prime Meridian has changed several times.

The lunar coordinate system should be convenient for those on the Moon and in space as well as those on Earth. It also should be referenced to an endogenous lunar feature, not another planet. The Lunar West Pole Prime Meridian system is an improvement over the present system for all users. Longitudes roughly from 0° to 195° are on the lunar nearside (includes libration) and 195° to 360° span the farside. Adding 5° to Earth's angle from the eastern horizon gives longitude directly. The all-positive numbering system makes computation of change or distance in longitude easier, and removes sources of error. This location of the Prime Meridian is clearly discernible from space: a naïve observer might easily pick Mare Orientale as a marker. The Lunar West Pole Prime Meridian system is useful, simple, elegant, intuitive, endogenous to the Moon, and conforms to modern standards.

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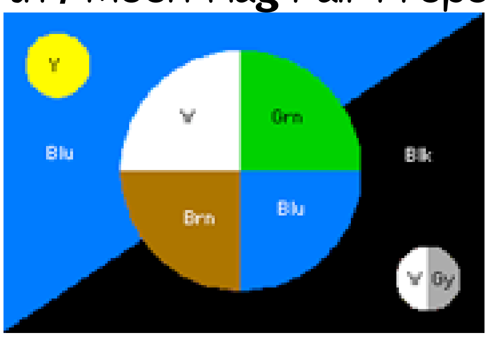
Earth / Moon Flag Pair Proposal

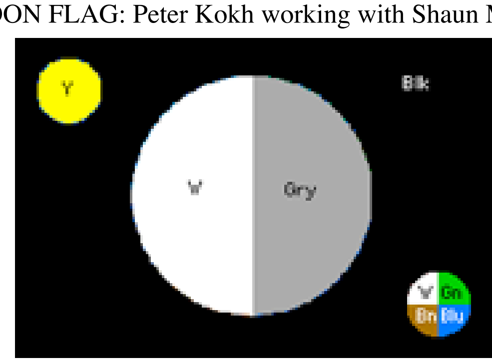


EARTH: Shaun Moss <shaun@MarsEngineering.com>

"This design is a stylized representation of Earth in space. The four colors of Earth (clockwise from upper left) white, green, blue, brown) are shown in the form of the quartered cross, which is the astrological symbol of Earth. The upper-left half of background shows the golden sun in the blue day sky, lower-right half shows the silver Moon in the black sky of night."

members.aol.com/kokhmmm/earth_moon_flags.htm

MOON FLAG: Peter Kokh working with Shaun Moss.



MMM #156 - JUN 2002

The Deep Silence of the Moon, and Humans

The Moon is now a very quiet place. How will that affect humans over the long haul? How will human sounds and noises play on the Moon? It is a more interesting topic than one might think. In this issue, we take up the subject and look at it from a wide variety of perspectives. Read "In the Still of the Night," =>> *below*

Crop Selection Criteria for Lunar Settlements

by Larry Jay Friesen <ljfriesen@peoplepc.com>

The topic of crop selection for extraterrestrial life support systems, and particularly for lunar bases and settlements, is one that has received some attention but probably deserves more. I would like to address it not because I know what crops we should choose, but because I would like to put forward for consideration some criteria we might want to consider when we are making our choices.

Sometimes, when we don't know the best answers, it is useful to frame the questions carefully. In the long term, lunar residents will quite likely grow a wide variety of crops, and probably some plants that are not crops - that is, are not grown for food or usable materials. But where should we begin? What crops would we want to start with, and what criteria might be important in making our selections?

To look for a good initial crop mix, we will probably want to use a multidimensional search space. In other words, we will want to look at several types of criteria at the same time. Peter Kokh mentioned one dimension of crop selection in Issue # 149 of the Moon Miners' Manifesto: flavor, and menu diversity. I may touch on flavor in passing, but I would like to concentrate on two additional parameters of the search space: growing conditions and nutrition.

1. What crops will grow best under lunar conditions?
2. What combination of foods could we grow, to most efficiently satisfy our nutritional needs, while eliminating the need for supplements imported from Earth, or at least keeping such imports to a minimum?

While I will concentrate on plant foods, I will touch on raising animals as well. In some studies and initial experiments for self-contained life support systems, I have observed a tendency to concentrate on crops familiar to the people doing the experiments: frequently crops grown on North American farms. I would like to expand our horizons and look both at the crops we are familiar with and at all sorts of food producing plants from all parts of the world.

Lunar Growing Conditions

Optimizing crop selection for growing conditions on the Moon is a multidimensional parameter space by itself. Among the parameters to be considered are lunar gravity, the lunar day/night light cycle, the lunar temperature cycle, availability of lunar resources (water, soil), and the choice of atmos-pheric conditions for the settlement. To learn how plants grow in lunar gravity, and how their productivity compares to the same plants grown on Earth, we will probably have to wait for actual experience on the Moon, or at least for variable-g centrifuge experiments in orbit*, on the International Space Station (ISS) or some other orbiting research facility.

Lighting Conditions & Cycles

Some of the other parameters, however, we can check on Earth. Lunar Day-Night Cycle: We will very likely be able to light the areas in our settlement where we grow our plants on any schedule we choose, whether it is the 24-hour day we are accustomed to on Earth, or something entirely different. But it might be worth while investigating how plants respond to the Moon's natural month-long day-night cycle, whether we expose our plants to sunlight directly, through windows, or light pipes in as has been suggested more than once in MMM*.

MMM # 66 p.7 JUN '93, "Let There Be Light: light delivery systems for lunar settlements need to be rethought" -- Republished in MMMC #7

MMM #74, APR '94, p. 7. "Sun Moods" and MMM # 136 JUN '00, p. 3. " Nightspan Lighting: Sulfur Lamps and Light Pipes" -- Republished in MMMC #8

If the crop-growing areas are collocated with the human habitation portions of a lunar settlement, the plants will, of course, receive whatever light on whatever cycle the inhabitants choose for themselves. But if crops are grown in separately pressurized volumes, more flexibility is possible. Might we find ways to maximize the use of the natural lunar day-night cycle, and thereby minimize the need for artificial light in the farm areas, thus minimizing overall power requirements for the settlement? *

[* This was the subject of the LUNAX - Lunar Agricultural Experiment Corp. efforts spearheaded by LRS member at large, David A. Dunlop in 1990-1. See http://www.lunar-reclamation.org/lunax/]

Selection of crops tolerant of extended periods of light and darkness can be part of this scheme. If we do have to supplement natural light, perhaps it is not necessary to hold strictly to a "12 hours light, 12 hours dark" timetable. For some crops, might it be enough to interrupt the 14 days of darkness with brief, occasional intervals of light? Or for crops that find 14 days of uninterrupted light difficult, may brief, occasional intervals of darkness suffice?

There are obvious opportunities for research here, to find what lengths of light, at what intervals, will be sufficient or optimum for crops, and what lengths of darkness, at what intervals, will work best during the lunar day. Some crops have a very rapid growth cycle: certain varieties of radishes, as one example. Might it be possible to grow such a crop from seed to harvest in a single lunar dayspan? This, too, would be a good research project. One place we might start our search for plants that can tolerate the long lunar day-night cycle is among plants that grow in far northern or southern latitudes. They may already have some pre-adaptation to extra-long days (during the summer) and extra-long nights (during the winter).

Temperatures and "Climates"

I might also suggest that we not restrict ourselves to plants already domesticated. We might, for example, experi-ment to see if roots or berries presently gathered wild by arctic and subarctic peoples can be cultivated. Lunar Temperature Cycle: Neither crops nor people can tolerate the extreme swings of the lunar temperature cycle, which goes from about 100 kelvin (-173° C) for the majority of the lunar night to around 400 kelvin (137° C) at noon on the lunar equator - far above the boiling point of water. But it may not be necessary to hold the temperature absolutely constant, either. Some temperature fluctuation may be desirable, even necessary. As Peter Kokh has pointed out, some crops require freezing or frost temperatures, at least for short intervals, in order to set fruit.

To search for crop plants that can tolerate the greatest temperature fluctuations (and thereby minimize our power requirements for heating and cooling the farm areas), we might again start by looking at crops adapted to high-latitude regions. We might also try desert-adapted plants. In many deserts on Earth, temperatures can swing from an extremely hot day to a quite cold night in a single 24-hour period.

Lunar Resources: Soils versus Hydroponics

Some closed cycle life support studies have used, or assumed the use of hydroponics. But as Peter Kokh has pointed out, and as studies of Apollo returned samples showed, many plants will grow quite well in lunar soil, at least in the basaltic type soils of the lunar maria. This shouldn't be a complete surprise, since basaltic volcanic regions are often fertile farming country on Earth.

Since water is scarce on the Moon (and this will be true even when we manage to tap the polar ice resources), hydroponics may not be the best use of the available resources. An agricultural system based on lunar soil, augmented as necessary, may require less mass imported from Earth. I am not dismissing hydroponics out of hand. It may turn out, that after an overall systems analysis, hydroponics are necessary or advantageous for all or part of a lunar farm system. I am saying we should not simply assume hydroponics and plan from there. If we do use lunar soil as the basis for our lunar farms, it would be a good idea to find out what plants grow best, and produce the most food per unit input, in lunar soil. Studies of this type can be started on Earth, using lunar samples, or more likely, lunar soil simulants, since the amounts of actual lunar samples are limited.

I also suggest, since water is a limiting resource, that we investigate what crops produce the most food per unit water input. One place we might look for such crops is among desert-adapted plants.

Atmosphere Conditions:

The Space Shuttle and International Space Station are pressurized to Earth sea level atmosphere pressure, 14.7 psi or 1 bar. But there is no absolute requirement to do this. Airliners, for example, are typically pressurized to the pressure at 8,000 feet elevation, with no ill effects on passengers. Lunar settlers may likewise decide to pressurize their settlements at something less that Earth sea level. For Moon gardens in pressurized modules separate from human habitation, lab, and factory space, we can choose to optimize atmospheric pressure and composition in the garden modules for the crops. But plants that share volume with humans, will have to live with whatever the people are breathing. If this is at less than Earth sea level, we might look at crops that thrive at high altitude as a starting point.

Nutritional Needs

When considering crops from a nutritional standpoint, I'd like to keep in mind that some nutritional needs are more time-urgent than others. For example: the body can store a supply of some vitamins adequate for considerable periods of time, but not others. The approach I will attempt to describe will require some input from nutritionists. I am not an expert in this area, so if some of our readers are, here is where you can offer some useful information.

I'd like to find out what the most time urgent needs for nutritional inputs are. Consider each type of input we need from our food: carbohydrates, fats, proteins, vitamins, minerals. How quickly will a lack of a given nutrient cause us problems? What will put us in sick bay fastest, if we lack it? Raw calories? Some vitamin? Some mineral? Our bodies store reserve supplies of some nutrients, and we can run quite a while without eating foods containing them. For other nutrients, this is not so, we must have frequent supplies in our food, because we cannot store them, or not very much of them.

As examples, would we come down with scurvy first, or beriberi, if deprived of the key vitamins? I would rank human nutritional needs in order of their urgency, with those whose lack harms us most quickly at the top of the list. When we're just starting our lunar gardens, it appears to me that filling these needs will start to pay off in reduced shipping costs for Earth resupply most quickly.

Once the "urgency order" is determined, I would find the plant that produced the greatest amount of that nutrient, per acre, or per plant biomass, or - in light of the discussion above - per unit water input, and put that plant at the top of my list for food crops. I would probably make exceptions if the crop or crops at the top of this list turned out to be something extremely slow growing, such as a long-lived fruit tree. Once my first crop was selected, I would find out how much of each remaining nutrient requirement that plant would provide. Those whose "minimum daily requirements" are met by the first crop would be checked off the list. I would then find the nutritional requirement at the top of the list among those remaining. The next step is to choose a crop which could most efficiently meet that requirement. Then we would need to find out how many "minimum daily requirements" for the remaining nutrients on the list could be met by crops one and two together. If any nutritional needs would still be unmet, a third crop would be selected that could efficiently meet the most "urgent" of the remaining unmet needs. This process would be repeated until a crop suite had been selected that could meet at least the minimum amounts of all the nutritional components a person needs to stay alive and healthy. Those that supply the most urgent nutritional needs would be planted first.

Food Animals & Livestock

If we are serious about cutting the umbilical cord with Earth, that is making a settlement *increasingly* independent of shipments from Earth, at least for life support, then at some point our farm and garden system will need to include animals. Not for protein - careful selection of plant foods can give us a balanced amino acid input - but for vitamin B12. This point was discussed in an earlier issue of Moon Miners' Manifesto. Yes, we can supplement our diet with vitamin pills,.but that means being tied to Earth for a very long time, because I suspect that complex organic synthetic chemistry will not be in the lunar industrial repertoire for quite some time.

As long as we need to raise animals, for any nutritional need, they will also contribute very effectively to the protein intake of the settlers, so we may as well include that in our nutritional computations for crop selection. Keith and Carolyn Henson mentioned to me at one of the early Princeton Conferences on Space Manufacturing, that it used to irritate the daylights out of their vegetarian friends when they could show that you can get more edible protein from the same amount of land by raising alfalfa and feeding the alfalfa to rabbits, than by raising soybeans. The reason for this is, of course, because rabbits can eat most of the alfalfa plant, while we humans can only eat the beans from the soybeans. There is enough meat on a rabbit that the overall efficiency of the system, from the standpoint of protein production for human consumption, is better than the soybean route.

Raising animals means, of course, that we must include in our crop list those we will use for fodder for the animals, if those include any not on our own menu. The first animals selected are likely to be small: perhaps rabbits, as mentioned above, or guinea pigs ["cavies" are a staple of Peruvian cuisine.] or chickens.

When lunar settlements expand sufficiently, they can optimize their crop and livestock mix any way they choose, but we are talking about the beginning stages, where available space is likely to be limited. Here we can use some input from people with experience raising animals, who know something about the food and space requirements, and the meat (or egg) production efficiencies, for various animal varieties.

I would hazard a guess that perhaps chickens are not the best first choice. From what little I know, their diet seems too much like ours, which would make them competitors for the same crops we are raising for ourselves. Rabbits, or animals with similar food requirements, may be able to eat some parts of plants, such as leaves and stems, that we can't, which makes their diet more complementary to ours, and probably would result in an overall higher efficiency in the system.

Our first domestic animals may be even smaller than rabbits or guinea pigs. Chef Emeril LeGasse, on one of his

Emeril Live programs on the Food Channel, happened to mention he was preparing herbivorous snails that are raised commercially. Snails may not be at the top of everyone's preference list, and many of us may be unfamiliar with them as a food item. But as much as some of us may want the "taste of home" when we're living on the Moon, if we are to pioneer a frontier, we had better be prepared to cope with new situations. That may include our diet, if a systems analysis tells us that some new and unfamiliar food can be produced much more efficiently than the alternatives. If someone tells me that I can go to the Moon, but a condition will be that I must eat snails, or silkworm larvae (considered edible in some parts of the orient, I have read!), or some other strange unexpected food, you had better believe I will at least make an effort to try them.

This wouldn't be the first time in history that pioneers have had to learn to eat strange new foods. When Europeans began to settle the Americas, they found themselves faced with turkeys, corn (maize to non-Americans), tomatoes, potatoes, and squash, to name a few of the foods offered by their new homeland. Many of us now consider these things great stuff, but in each case, the first settlers had to overcome the barrier of unfamiliarity.

As I admitted at the beginning, I don't have final answers. What I hope I've done is frame some of the questions in a manner that will both provoke discussion and research, and guide that research in useful directions. Some of the work of finding how potential crops respond to lunar growing conditions may have to wait until we actually have lunar bases or settlements. But it appears to me that large chunks of that research can be done right here on Earth. I suspect that while some research may need to be done on nutritional values of crops (especially crops not commonly grown in North America or Europe), much of the information we need about nutrition is known. What we probably need here are some experts in nutrition and agriculture to help us pull the information together and organize it. Any nutritionists or farmers out there who can help us? **<LJF>**

The Still of the Night

The Moon is a *very* quiet place ... *now!* How will that Change with the Sounds of Settlement?

by Peter Kokh

Recently, Moon Society member John Schrock wondered about the Sounds of Silence on the Moon:

> *"I perceive in my own mind that the Moon is a quite place. No wind, no trees no animals, no cars nor trains. With human settlements, rockets landing and taking off, and the workings of manufacturing equipment and other things will add sound.*
>
> *"What are the long term effects to humans of a lack of natural sounds, while landed on another space object far from their birth place, and working every day for at least the near future with [only] equipment sounds, and the constant checking of meters and gages and screens with data and lights blinking or lights constant on or lights constant off and of creaks in the shelter and expansion of metal from temperature extremes and meteor showers and no taped earth sounds as the equipment is down and the budget does not allow for new equipment and all because man wanted to sail away from home?"* - John R. Schrock

Sounds and Vibrations

NASA is unlikely to have attempted to make any sound recordings on the Moon for the simple reason that sound requires atmosphere, and the Moon has none to speak of. Yet, as geologically and biologically dead as the Moon is relative to Earth, there are events on the Moon - from time to time - which would make sounds, if there were an atmosphere to carry them. Landslides, meteor impacts, etc. In the absence of appreciable atmosphere, these events can and do still transmit vibrations that ricochet through the fractured powder-blanketed surface. And NASA has left seismographic equipment on the Moon to register the telltale signs of such events.

Once humans are on the Moon, how much of our activity will be noticeable as vibrations? Perhaps not as much as one might think. The loose regolith of fractured stone and stone-derived powder will damp out most low-level vibration - vibration that does not reach the fractured bedrock below.

Inside our spacesuit helmets

Moonwalkers, spacesuited personnel on surface excursions, while exploring or prospecting or performing service duties, will hear the sounds of their own bodies, the whir of suit respirators and circulation equipment, and, of course, radio transmissions from others. But no nature sounds, no wind, no rustling of tree leaves, no chirping of birds or insects, no babbling of brooks, not even the sound of stones being knocked aside by their boots.

John raises the question of sensory deprivation from this unnatural quiet. Will it have long-term effects, at least for some individuals? Will morale and productivity suffer?

Actually, many humans have been in similar situations on Earth, at least briefly, where nature was unusually quiet. Some may chose the sounds of man-made music anyway, and be so accustomed to their Sony Walkmans that they would not ever notice that Nature had nothing to say, or sing, or shout.

I vividly recall listening to Jesuit Brother Guy Consolmagno S. J. telling a rapt science fiction convention audience of his experiences on the Antarctic expedition that found the alleged Mars Meteorite. He used a pair of slide projectors to take us visually to the scene, he had playing in the background the same symphonic music that was playing in his Walkman. Antarctica, absent the howling winds, can be as quiet as the Moon. But he seemed to be in seventh heaven nonetheless and succeeded in recreating the experience in each of us.

Inside the Settlement: Indoors & Middoors

Life inside personnel quarters or private residences, or within labs and other pressurized work and activity spaces on the Moon might not be that much different, sound-wise than life "indoors" here on Earth. But there will be differences. No storm sounds from howling winds, driving rain, hail, or thunder will ever provide the stuff of conversation around the dinner table, at a bus stop, or at the local bar happy hour.

Yet that is too simple a statement. Recall our distinction between indoor, middoor, and outdoor or out-vac. Middoor spaces are the air-filled spaces represented by pressurized halls and walkways, streets and transit tubes, parks and squares, etc. They are "outside" homes, offices, and workspaces, but "inside" the "hull-plex" of the settlement. One's habitat may be insulated to the point where no middoor sounds can penetrate, but such buffering is not strictly necessary and may be a matter of choice.

Some may choose to tune their habitat speaker system to "play" the background activity noises of a nearby square, park, or market. Of course one could supply canned noise, but why when the sounds of real live life activities are available in unscripted format?

In the middoors itself, a variety of "nature sounds" can be provided. As the middoors areas will host the bulk of the shared biosphere, it is logical that there will be song birds and sounds of other planned urban wildlife. And instead of the steady drone of invariable ventilation, the air flow circuit between the settlement spaces -- from farms and orchards to residential areas, schools, commercial areas, offices, industrial areas and back through the farms for cleansing -- can be varied in direction and force to produce breezes and wafts within set ranges. This would provide for more random accompanying noises -- in the rustling of leaves, for instance.

If "rain" is programmed into the middoor climate calendar, that too will have an effect on sound transmission. So will dawn and dusk, whether as a service of the rising and setting sun or as a programmed feature of artificial lighting.

Air quality in middoor spaces will benefit greatly from exposed water features: fountains, water falls, babbling brooks, and as mentioned, occasional programmed rain. These generate welcome "white noise." To some extent, as we noted in MMM # 154 April '02, p. 8. "Homestead Ambiance: Waterfalls & Fountains," such sounds can easily be provided within private spaces as well.

There is a danger of internal noise pollution, however. Long straight line pressurized cylinder halls, walkways, and settlement streets will tend to channel sounds bullhorn style. The noise of traffic, even from electric vehicles, could become oppressive. The roar of loud conversation in crowded spaces could carry. We'll have to design in sound-muffling acoustical surfaces to keep accumulative sound levels down to a pleasant level. Just the right amount of texturing in surfaces should do the trick, along with intermittent sound-absorbing barriers and breaks to straight line transmission: trees, sculpture walls, etc. A little imagination and due proactive attention to the problem should take care of it. But it'd be naive to think that there won't be "learning experiences" and a "learning curve."

Intrusion of Out-vac Surface Sounds & Vibrations

Will we "hear" the vibrations of landing rockets at a nearby spaceport, of heavy cargo-laden trucks and regolith-moving equipment on adjacent roads? Vibration will work to weaken seals and could lead to eventual pressurization leaks. So it seems important to have an overall settlement plan that isolates regular and periodic vibration from the principal pressurized areas. Loose regolith not just as shielding above, but as bedding below and to the sides might help. We'll have to do on site tests to see how good such sound insulation is, and weather or not it degrades with time, e.g. through gradual compacting. If necessary, foamed glass and other buffer materials could be pressed into service.

What about Industry

It would seem logical to sector industrial activities between those that are low in vibration and low in waste heat production for incorporation in the settlement areas proper, and those with either high vibration levels and/or high waste heat output to well separated areas at a thermal and sonic buffering distance. Some of the later might be automatable and if they did not require pressurization, could be housed under simple ramadas or sunshades on the open surface, areas open to the vacuum but perhaps baffled to reduce dust intrusion.

If most of the high impact high vibration industrial activities can be automated for unpressurized areas, the incidence of industrial *tonitus,* severe and constant ringing in the ears, should be much less common than on Earth. This would be a big plus.

Out-Vac Silence

Out on the surface, silence should remain supreme. With no air to transmit vibrations from settlement activities, and with little of that seeping into the bedrock, anyone outside would hear only the sounds from within his or her own moonsuit, plus whatever he or she chose to pipe in.

In some locations, out of line of sight with a satellite or radio tower, below the surface exploring a lavatube, for example, we'll need more than radio. We'll have to carry our own library of music and sounds with us -- or risk eventually going insane.

Near term problems

Given the above considerations, sound, or the lack of it, does not seem to pose a morale, health, or productivity problem for lunar settlements. But in the near term, spartan starter outposts may not be quite so friendly. Sound problems, both too much and too little, are likely to be the source of many early complaints. Morale and productivity will be at stake so we can only hope that the engineers and architects on Earth will be proactive and try to stay ahead of such problems, designing them out, or trying to. It will be a learning game, and it will be in everyone's interest to learn quickly. It's just the Prelude.

Summary

The Moon will remain overall a quiet silent place. Human activities will no more pollute the airless lunar silence, than they will the ground water, there being none of that either. We must remain within our pressure hulls: helmets and moonsuits, space ships, surface transports, and settlement spaces.

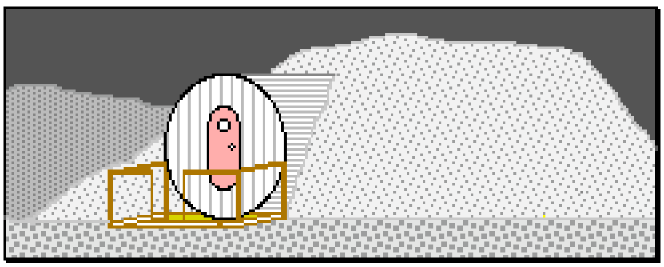
Inside those hulls, small h or big H, we will be alone only at the outset. Long term we cannot survive just by ourselves. On Earth, our existence is tight-hosted by a biosphere full of plants and animals. To succeed on the Moon we will have to do our best to recreate those conditions, reencradling ourselves with fellow-traveling populations of Earth life. Think of space as a great flood. Think of our transmigration to the Moon as a Noah-like journey.

If we succeed in surviving and thriving on the Moon, we will not be doing so alone. And to the extent that we bring water, select plants, and select wildlife with us, we will have much more than just ourselves and our machines to listen to. We will be able to enjoy many of the sounds of Nature as we do on Earth -- if perhaps a little less on the wild side!

Perhaps few of us have ever sat down to list our “favorite sounds.” We take them for granted. Our descendants on the Moon will have theirs as well, and perhaps take them for granted also.

On this score I think we’ll be okay. **<MMM>**

MMM #157 - AUG 2002



Porches on the Moon?

The very idea of a lunar habitat having a “porch” seems absurd at first thought. But on Earth, porches serve a number of useful functions, and we examine the question from this viewpoint -- how could we serve these functions for lunar pioneers? The whimsical sketch at right is not quite an illustration of the applications we foresee. **==>** *below*

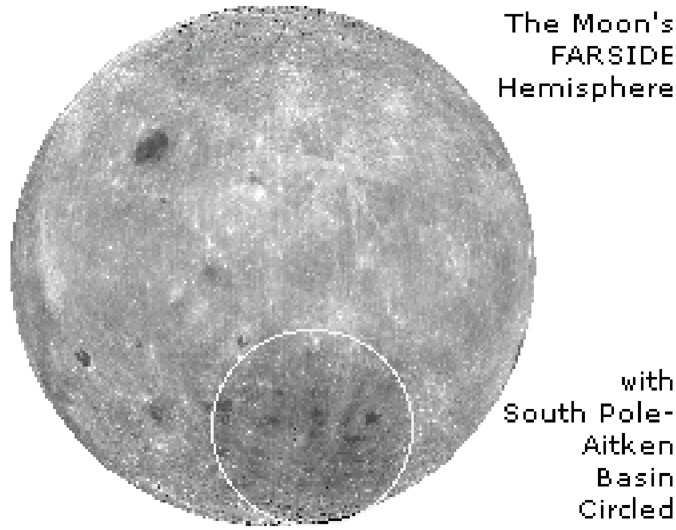
Planetary Scientists show born-again Curiosity about the Moon!

by Peter Kokh

When scientists looked at the first photos of the Moon’s previously never seen Farside hemisphere they were surprised by an apparent major difference from the hemisphere always turned towards Earth. More than a third (38%) of the familiar side of the Moon is covered with dark lava plains called “seas” or “maria” (Latin: mare, maria = sea). But similar features seem to cover no more than 2% of the hemisphere forever turned away from Earth. Could it be that no large impact basins formed on the farside?

Actually, both topographic and altimetry evidence are that there are just as many large impact basins on the farside as on the nearside. The difference comes in what did and did not happen after the basins formed. On the nearside, where the crust is thinner, molten lava magma from the Moon’s mantle eventually worked its way up through the fractured basin bottom crusts to flood the basins, turning them into the maria we are familiar with today. But on the farside, where the crust is thicker (100 km vs. 60 km) owing to a deformity in the Moon’s shape caused by its tidal lock with Earth, the magma reached the surface in fewer places.

Indeed, the Moon’s largest impact basin lies not below the Ocean of Storms (Oceanus Procellarum) but in lower farside. Known as the South Pole-Atken Basin, it is the largest and deepest on the Moon. But with no more than local patchy lava flooding, it is not called a “mare” but a “thalassoid” (Greek: qalassa thalassa = sea). The established name comes from its southernmost (south pole) and northernmost (Aitken crater) easily identifiable features.



SPA, as it is known in planetary science short hand, is unusual in more than its size (1,500 miles or 2,400 km in diameter - covering 90% of the span between the S. Pole and the equator!) and depth (12 km = 7.5 mi. = c. 40,000 ft) but in the as yet uncertain composition of its floor. Impact theory, as we presently understand it, would demand that the floor of this immense basin consist largely of mantle material exposed when the crust above was blown away. But Clementine and Prospector data cannot confirm this. The uncertainty, festering since the Lunar Prospector results were released in 1999, has planetary scientists in a dither. Gone is the previous comfortable posture of most planetary scientists towards the Moon. “We’ve been there, done that, and we understand all we really wanted to know about the Moon.” Gone too is their post Apollo exclusive preoccupation with Mars, Europa, and Pluto.

Unexpectedly the Moon is very much back on the must do agenda of Planetary Geology. A robotic mission to recover samples from the floor of the SPA Basin is suddenly vying for equal attention with strongly supported Europa Orbiter and Pluto Flyby missions. A National Research Council group has recommended prioritizing such a mission as a near term Discovery Mission. NASA seems to be listening.

Easier said than done

Yes, we have sent probes to the Moon before, and the Russians have done a few robotic lunar sample return missions. But there is some little fact that puts an SPA sample return mission well beyond that technology. Simply put, the target area is on the Moon’s Farside, in the permanent radio shadow, out of reach of teleoperators stationed on Earth. We see three ways to get around this obstacle.

1. Total robotic control using expert programs and what we have ready to go of AI, artificial intelligence. And we cross our fingers!
2. Operate in tandem with a lunar orbiter that can act as relay for teleoperation *when* the orbiter is above the surface probe’s horizon.

3. Put a relay satellite in the L4 or L5 Lagrange areas of the Moon's orbit, 60° ahead or behind the Moon in its orbit respectively. The easternmost and westernmost portions of the SPA basin would be in sight of one or the other.

What's in it for us?

Hey we're glad to hear that NASA is changing its mind about returning to the Moon. And we share some of the planetary science curiosity. But what will any of this matter for those of us who want to see a permanent resource-using settlement on the Moon? Here are some reasons for *us* to get excited.

- This same robotic technology can be used to get samples of lunar polar ice deposits - a resource exceedingly important for lunar pioneering
- The SBA basin floor is the largest unsampled type of lunar terrain and just may contain unexpected resource concentrations
- This mission could be a precursor to the establishment of farside observatories on the Moon

For more, go to:
www.space.com/ missionlaunches/robotic_moon_020801.html

<MMM>

PORCHES ON THE MOON?

by Peter Kokh

The Inspiration for this essay was a recent 7-28-02 HGTV Cable TV special "Americans & Their Porches"

Porch: 1. an exterior appendage to a residence, forming a covered approach to a doorway. 2. *U.S.* a verandah.

A brief ancient/modern history of porches

The porch or portico is an ancient amenity going back at least two thousand years.

Porches became a common feature of homes built in the 19th Century in America, offering a middle ground between the inner sanctum of the home itself and the outside world, specifically the neighborhood beyond. They have served several functions:

- greeting neighbors and passersby without having to invite them inside, thus enjoying the pleasures of civility and neighborliness
- enjoying the weather within reach of shelter; sunrises and sunsets, approaching storms, breezes
- nature watching: sunrises and sunsets, trees and gardens, birds and other wildlife
- storing paraphernalia used outdoors
- shedding dust and mud before entering the home

Porches began to disappear from both new and old construction after World War II. New housing was needed at the lowest no-frills price possible. In old housing, porches were converted to extra indoor rooms (bedrooms, 3-season rooms) for growing families more cheaply than by building an addition from scratch. Television was new and proved to be an addictive lure away from porch-sitting (people in general seemed to become more self-involved.) Air conditioning made indoor relaxation more appealing.

Small town America was not immune to these changes, but seemed to hold on to porches longer. The pendulum is swinging back. Boredom with the TV/Cable boob tube passive wasteland, a purposeful reemergence of neighborliness, a rediscovery of the pleasures of relaxation and real weather -- all these are luring more people to their own bit of outdoors. There is a growing "new urbanism" that is rediscovering the city (as opposed to the suburbs) and the greater opportunities afforded by higher density and diversity to enjoy the pleasures of more frequent contact with neighbors. Porches build community.

Functions of Porch Analogs on the Moon

The essence of a porch is an interface between "home/habitat" and "world." On the Moon. in pioneer settlements, the opportunity to establish such an interface occurs on three levels:

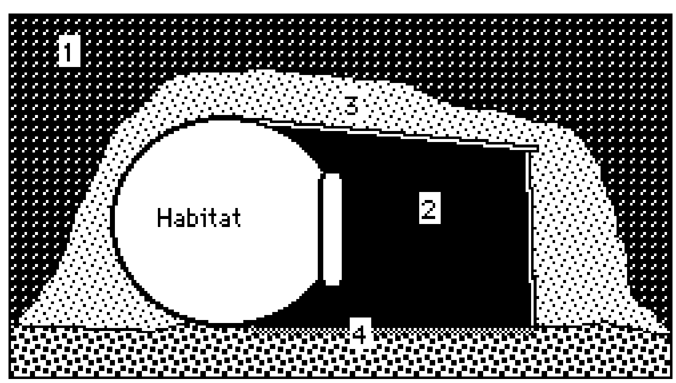
1. outside the airlock (if there is one)
2. outside a door opening onto a pressurized public passage
3. inside adjacent to an indoor "yard" or solarium garden space or "Earthpatch"

Out-vac "Porches"

Our illustration on the front cover of this issue may seem whimsical. But when you think about it, an airlock-connected "porch" could be useful:

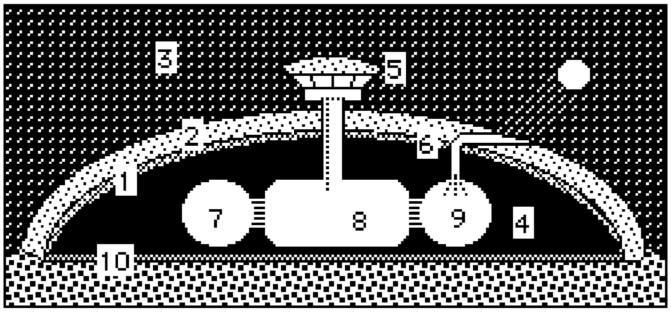
- provide a place and the means (a special "doormat") to *shed troublesome moondust* before entering - we talked about ways to do this in MMM #89 OCT '95, pp. 5-6 "Dust Control" (design of a special turtle-back suit and mated airlock)
- a place to *store equipment* used outside
- if roofed, shade from the glare of the sun
- *relief* (if the roof-canopy has a sufficient regolith blanket) from micrometeorite rain and cosmic ray exposure while doing routine outdoor chores like changing out fuel tanks - this is the concept of the "Ramada" which we talked about in MMM #37. JUL '90 pp. 3-4 and in MMM # 89, OCT '95 pp. 3-4 "Shelter on the Moon"
- an opportunity if so desired, to *customize* the out-vac entry to their personal family haven

Here is an illustration of the porch canopy concept from the MMM #89 "Shelter" article:



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

Another way to achieve the same sort of protection is to place habitat structures within or under a shielded hanger-like shed. Another illustration from the same article:



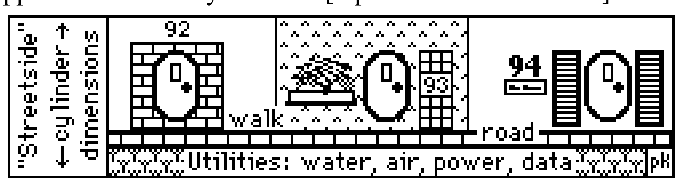
KEY: (1) Space Frame Arch, Fabric Cover; (2) 20 cm or more regolith dust shielding; (3) exposed vacuum, radiation, micro-meteorites, UV, solar flares; (4) protected lee vacuum service area; (5) observation cupola with ladder shaft to habitat space below (7, 8, 9); (6) broken-path solar access via heliostat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

Ways to customize one's out-vac surface entrance (color, texture, and design options) were discussed in MMM #55 MAY '92, p 7, "Moon Roofs." [reprinted in MMMC #6]

Middoor Porches

The concept of the "middoors" is simple. In lunar settlements, there will be pressurized climate-controlled shielded spaces "outside" individual habitats and work structures but "inside" as opposed to the vacuum and radiation-washed exterior surface "out-vac." Recently, we wrote about the role of these middoor spaces in supporting a large portion of the settlement biosphere: MMM #152 FEB '02, pp. 5-6.

In this concept of the modular settlement, growing naturally a module at a time, each residence unit has an air-lockable entrance on to a pressurized residential thoroughfare. The street frontage serves as the interface through which individual-private and shared-public worlds meet. Thus that entrance façade will probably be a more popular canvas for a distinctive statement. "I'm unique and proud of it." Here is an illustration of some possibilities from MMM # 109, OCT '97 pp. 3-11 "Luna City Streets." [reprinted in MMMC #11]



Sidewall section of a residential street, suggesting how homedwellers might customize entrance façades. *Ibid.* p. 6

Now these "middoor" entrances provide an architectural opportunity to do more - to provide a "porch" enabling setback or easement on the residential street. These can be left empty or unstructured, but may eventually entice home-dwellers to use them as semiprivate, semipublic spaces where they can relax and enjoy opportunities to socialize with their neighbors and passersby. Such a "porch" will also allow them to enjoy the less controlled middoor climate -- in the middoors, temperatures might be allowed to swing in natural dayspan-nightspan (29.5 day) cycles as well as seasonal cycles fitting for the kinds of plants (and wildlife) desired. It will also provide "at home" relaxation space from which to enjoy any settlement "urban wildlife": birds, butterflies, squirrels, etc.

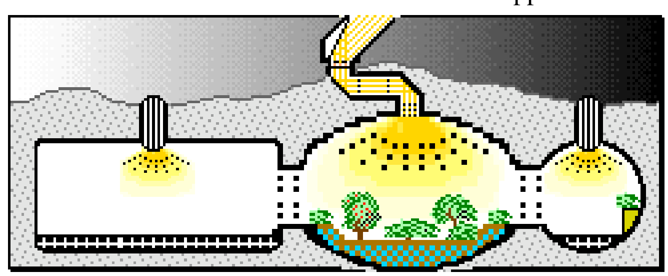
The Middoor porch would probably not have a roof or canopy, sharing the protection of the unpressurized street itself. But railings, hanging pots and planters, swings and gliders and other seating and tables might become a common sight.

The pioneers will have other opportunities to socialize and bond, to be sure: at school, at work, and in voluntary group activities. But there is something special about the unprogrammed unstructured opportunities for "neighborliness" that a "curbside" porch brings. It is an easy place to be, within reach of one's inner sanctum on a moment's notice or whim. An "at home" place to enjoy living in a settlement.

It is not enough to build the settlement physically, nor enough to provide an ample and varied modular biosphere. It will be essential, if a human presence on the Moon is to truly endure and not be just another false start leading to history's most expensive "ghost town" to aim beyond those two goals. We have to do what it takes to build the settlement *as a community*. The "middoor porch" may have a strong supporting role to play in this effort.

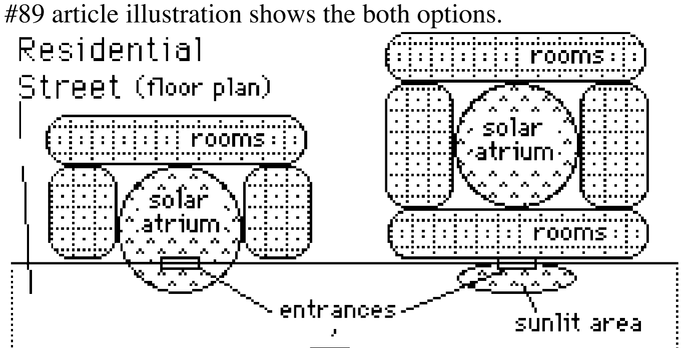
Solarium Garden Patios

One of the noted pleasures of porch-sitting, enjoying the surrounding trees, shrubs, and flowers, to be sure does not require street-facing placement. A backyard patio will do as well. On the Moon, homesteads are more likely to "interiorize" any private "yards," that is, to have garden space or "Earthpatch" atrium solaria in which they can garden away to their hearts' content. See MMM #148 OCT '01 pp. 3-6.



If you have such a pleasant space within your home, full of greenery, flowers, fresh air, fragrances, and sunlight, why not have a place along its perimeter to sit and relax and commune?

It is not a matter of choosing to have a curbside porch and an interior atrium patio -- lunar homesteaders can have both. But depending on the architecture, they could have both in one. In other words, put the atrium solarium to the front of the house so it opens onto the streetscape as well. The MMM #89 article illustration shows the both options.



Strange as it sounds at first, the "porch" may become a commonplace of lunar pioneer life. **<MMM>**

Cobalt Blue & Other Substances From Lunar Regolith

by David A. Dietzler, St. Louis, Mo. 7/6/2002

Prospector Pete [Peter Kokh] has described the manufacture and use of paints made with metallic salts dissolved in sodium silicate. Only materials available on the Moon are used. Here is a process, which is by no means the last word, for getting necessary substances from lunar regolith.

1) Roast regolith to drive out H, N, CO, CO2 (carbon will react with oxides), S, He 3, He 4, Ne (and all other noble gases). Separate volatiles thru fractional liquefaction. There are also traces of fluorine (140 ppm), chlorine (14 ppm), bromine (0.1 ppm), and iodine (0.0006-1.4 ppm) in the regolith, but they are probably in the form of salts that could be leached out of the regolith with carefully recycled water. Calcium fluoride is not soluble in water and these halogens may be bound in silicates, so leaching with water may not be useful. Barium at 200 ppm is present in the regolith most probably in oxide form. Barium oxide is soluble in water, unlike most oxides. It reacts with water to for barium hydroxide. The simplicity of water leaching is appealing.

2) Use electromagnets to separate ilmenite grains (FeTiO), iron, iron oxides, cobalt oxides (Co 25 ppm), nickel oxides (Ni 200 ppm), troilite (FeS) from roasted regolith. Reduce with heat and hydrogen to yield water and hydrogen sulphide gas. Electrolyze water to recover hydrogen and store oxygen. Hydrogen sulphide is either electrolyzed or pyrolized to recover hydrogen and get sulfur. Heat the metals with carbon monoxide to produce carbonyls of iron, cobalt and nickel that can be formed and decomposed at different temperatures to get the pure metals.

This is called the Mond Process. Iron composes about 14% of the regolith and will form iron pentacarbonyl (Fe(CO)5). This boils at 103 C. and decomposes at 200 C. Nickel tetracarbonyl (Ni(CO)4) boils at 43 C. and explodes at 60 C. Caution will be required when decomposing small amounts of this substance at a time. Cobalt tetracarbonyl (Co2(CO)8) melts at 51 C. and decomposes above this temperature. If the mixture is heated high enough to distill the iron and nickel, the cobalt carbonyl will decompose.

To separate the cobalt and titania residue that will be leftover, the mixture could be roasted with carbon monoxide again to reform cobalt tetracarbonyl. Since this is soluble in alcohol, ether and carbon disulphide, it will be easily washed out of the mixture then heated and decomposed to recover CO and obtain pure cobalt for our blue pigments. Titania will remain and this will be carbo-chlorinated and electrolyzed to get pure titanium and oxygen.

Carbon for CO will be imported and traces of carbon extracted from regolith will be used to replenish losses due to leakage. Organic solvents will be handled in a similar manner. Now, all we need is some sodium and silicon oxides to get sodium silicate to make paint. Sodium hydroxide heated under pressure with silicon dioxide will produce sodium silicate. Sodium hydroxide is made by electrolyzing aqueous solutions of sodium chloride in chlor-alkali membrane cells. Hydrogen and chlorine will be imported, recycled and traces from the regolith used to replenish leakage losses. We will also need aluminum to make cobaltous aluminate (Co(AlO2)2) for our beautiful blue paint.

3) Take the roasted and magnetically beneficiated regolith and leach it with hydrofluoric acid. This will produce water and silicon tetrafluoride gas that will be boiled off (some UF6 also, perhaps). That water will be electrolyzed to recover hydrogen, the oxygen stored for many purposes and the SiF4 will be decomposed at high temperatures to get pure silicon which composes 20% of the regolith and recover fluorine. This will leave a pile of fluoride salts behind. These will be heated with silicon (silico-thermic reduction) to make more SiF4 gas that will be decomposed for recycling. Since the SiF4 will evaporate from the mass, the reaction will be driven strongly to the right. Equilibrium won't stop us! 4XFl + Si = 4X + SiF4

4) Now we have a granulated (hopefully) mass of free metals that must be separated. Zinc is refined by distillation because of its low boiling point of 907 degrees Celsius. There's only about 15 ppm zinc in regolith, but we want to get it. Although most of our magnesium alloys will be made with aluminum, silicon, thorium and manganese; we might want some zinc for some magnesium alloys and other special purposes including plant nutrition. We will roast this mass of metals in a solar or electric furnace to boil off and distill sodium (3300 ppm), potassium, phosphorus, any remaining sulfur, cadmium, selenium, arsenic, rubidium, cesium, mercury and zinc.

All of these boil at lower temperatures than zinc. Some are present only in traces. Mercury is almost non-existent at 0.0006-0.013 ppm, meaning we'll only get a few hundred grams to a few kilos from a million tons of regolith, but how much mercury will we need? We will acquire substantial quantities of sodium to make sodium silicate for paints. We will also have some potassium to make potassium silicate which might also be of use. We will have silicon for PV cells and roast it with oxygen to make pure silica for glass and making sodium silicate.

5) Now we need aluminum to make cobaltous aluminate. Various chemical processes will be used to separate the remaining metals: aluminum, magnesium, calcium, manganese, chromium and trace metals including copper (11 ppm). Sulfuric acid leaching, electrolysis, electrostatic separation similar to the action of a mass spectrometer, and other methods will be applied. Much has been written about this by O'Neill and company. The CD-ROM in the 3rd edition of The High Frontier may be consulted.

It may also be possible to heat this mixture with carbon monoxide to produce chrominum hexacarbonyl (Cr(CO)6) and manganese carbonyl (Mn2(CO)10). Manganese carbonyl melts at 154 C. but begins to decompose at only 110 C. Fortunately it is soluble in most organic solvents. Chromium hexa-carbonyl is not soluble in alcohol, ether or acetic acid; so one of these will be used to draw off the manganese carbonyl and leave the chromium carbonyl behind

The manganese bearing solution will be distilled, the organic solvent recycled and the carbonyl decomposed with heat to get manganese and recover CO. The chromium carbonyl melts at 150 C. and explodes at 210 C. This could be a problem. It is slightly soluble in iodoform and carbon tetrachloride. Multiple extractions with these solvents after the manganese carbonyl is removed will be performed to get the chromium out of the Al, Mg, Ca, and trace metals mixture.

Organic solvents may be boiled off and distilled at lower temperatures by taking advantage of the free vacuum of space. Chromium carbonyl decomposes when solutions are exposed to light. Photochemical decomposition may be less violent than heat decomposition to get the chromium. Other transition metals like vanadium, niobium, tantalum, molybdenum, tungsten, rhenium, ruthenium, osmium, rhodium and iridium; traces of which some of these are found in lunar regolith, also form carbonyls that may be extracted.

The Al, Mg, Ca and trace element rich residue could be mixed into molten sodium hydroxide. Magnesium will float on top and be skimmed off. Aluminum will dissolve into the alkali which can be poured off and boiled down. Alumina rather than pure aluminum will probably remain due to reaction of aluminum with sodium hydroxide and this can be purified with the Alcoa process. Calcium and traces of other metals will remain to be purified by various processes. Cobalt, alumina and sodium silicate for azure blue paint will be produced along with many other substances when this point is reached. **<DD>**

REFERENCES: The regolith elemental composition data in this paper was obtained from **The Lunar Rocks** by Brian Mason and William G. Melson, Wiley-Interscience, New York: 1970.

Chemical data obtained from **Hawley's Condensed Chemical Dictionary** 11th edition revised by N. Irving Sax and Richard J. Lewis, Sr. , Van Nostrand Reinhold Co., New York: 1987

The use of sodium hydroxide to extract magnesium and aluminum is described in the Artemis Data Book, "Sodium Hydroxide Method for Extracting Oxygen from Lunar Minerals" by Dr. Larry J. Friesen, 3/20/00, available:
www.asi.org/adb/02/02/03/sodium-hydroxide-method.htm

Sodium Silicate / Metal Oxide Paintings

[See article at Right ===>>]

"Moon Garden #1" Peter Kokh

"Portrait" Megan Storrar

"Stereochromie" & the Prehistory of "Lunar" Waterglass Paints

by Gerald J. Grott <jgrott@cci-29palms.com>
[Email to KokhMMM@aol.com, September 16, 2001]

Early applications of "Stereochromie"

The first recorded origin of painting with waterglass and inorganic pigments was about 1840. It was known as 'stereochromie' and most university libraries have one or more references under that name. Hundreds of buildings in middle Europe still sport external paintings in bright colors though they are over a century old. The shroud of Turin, scores of feet high, was painted on linen and hung in a German Cathedral until destroyed by Allied bombs in WWII.

I myself started with this about 50 years ago. My original purpose was to flame proof wood with bright colored paint that soaked in. It worked very well as, on exposure to high heat, the wood would char but not burn.

In the 1970's we started a new business to commercialize the matching of the natural colors of rocks, particularly "Desert Patina", so that rock surfaces exposed by earth moving and blasting can be economically restored to a permanent matching surface coloration. We purchased the sodium silicate in numbers of 55 gallon drums. Unfortunately, our young manager died of cancer and none of us chose to leave our own businesses to run that one and we let the business die.

Methods & Tricks of the Trade

For painting pictures and illustrations, most any of the truly insoluble inorganic pigments are compatible with sodium silicate. However,you must be very careful not to have any contamination with soluble *carbonates* or *sulfates*. These are in detergents and soaps so you must rinse surfaces carefully before painting.

Also, avoid painting on cloths that have sizing in the fabric. Sizing in new cloth will almost always cause flaking or other decrepitation of the silicate. As history shows, unsized linen is a good base.

Magnesium oxide is a good material for reacting slowly with sodium silicate to form a 'permanent' rock like coating.

I have several full sized notebooks of R&D regarding the use of sodium silicate base materials for sealing surfaces against moisture penetration and particularly for avoiding deterioration of marble objects or masonry of, or containing limestone or magnesite.

You are on a good course. I wish you good luck.

Jerry Grott

[Editor: I am grateful for Jerry's advice, but have yet to take time to try out his "tricks of the trade."- PK]

[Editor: note to the MMM Classic #16 reprint of this item. We were experimenting with sodium silicate based paint. Now Sodium and Potassium are closely related element, and it appears that **Potassium Silicate paints**, now being produced commercial as "all mineral, zero volatiles, paints" are fully stable and do not exhibit the deterioration over time of the bond with the substrate being painted. This is an option for lunan artists. We can't wait to try them out! 06-21-2007 - PK]

MMM #158 - SEP 2002

Farming on the Moon

by Dave Dietzler <pioneer137@yahoo.com>

Proposed Showstoppers for Lunar Agriculture

It has been argued that lunar agriculture is not feasible primarily because of the power demand for crop illumination. Greenhouses will need thick glass roofs, crops will be killed by solar flare radiation and overheating of the greenhouses during the two week-long lunar day will occur. None of these arguments are valid, and they reduce the credibility of the Mars First camp, of which most Lunans are actually members.

Thick glass roofs will not collapse in the low gravity of the Moon. Unshielded greenhouses on the surface would be exposed to temperature extremes that would cause expansion and contraction of materials that could lead to cracking and other structural failures. Micrometeorite damage is another hindrance.

However, ... Underground piped sunlight by dayspan

The fact is, greenhouses will not be used on the Moon. Fresnel lens collectors and light pipes will transmit sunlight to farm chambers in sub-selene lava tubes which might be hundreds of feet in diameter and many miles long. Areas inhabited by humans in these lava tube cities will also be lit by light pipes and skylights. Underground farms will enjoy a constant temperature of a few degrees below zero in the surrounding rock rather than 250 °F. days and minus 250 ° nights. It will be easy to warm the chambers up to 72 °F. with waste heat from nuclear reactors. Radiation from galactic cosmic rays and even the strongest solar flares will be no problem deep beneath the Moon. Micrometeorite punctures will be unheard of. Overheating or "super-greenhousing" will not occur.

And sulfur lamps during nightspan

Illumination during the two-week long lunar night will be produced by microwave sulfur lamps with flexible fiber optic light-pipes that direct the light to the places where it is needed most. Light will not simply be scattered all over the place to be absorbed by the stone walls. Sulfur lamps will provide light in the visible range with very little infrared or ultraviolet. These revolutionary light sources can produce 95 lumens per watt.[1] Incandescents yield only 20 lumens per watt and fluorescents give 50 lumens per watt. Sulfur lamps don't even have electrodes to burn out!

How much light?

In the past, illumination recommendations were not as high as today's. In 1925, A Text-Book of Physics suggested that night time street lighting required less than one lumen per square foot. The average living room only a few lumens per square foot. Offices and classrooms needed 5 to 10 lumens per square foot. Workplaces where fine handicrafts, engraving, sewing or drafting were being done needed 10-20 lumens per square foot.[2] Today, we find values of 75 foot-candles (one ft. candle= one lumen/ sq. ft. or 10 lux) for reading and office work, 50 ft. c. for machine operation and 50-300 ft. c for bench work.[3]

The noonday Sun gives off 10,000 lumens per square foot at Earth's surface! Plants need more light than humans and animals do, but not this much. Many plants only need 200 lumens per square foot for good growth! The small tropical Chinese Evergreen plant, Aglaonema modestum, only needs 100 lumens per square foot (same thing as 100 foot candles) and can get by on as little as 10 lumens per sq. foot.[4]

The Bamboo Plant, Chamaedorea erumpens, requires just 100 to 150 foot candles. The coffee plant, coffee arabica , a necessity for us groggy old lunar prospectors and rich travelers, needs 150 to 1,000 lumens per square foot.[5] Tomatoes, sweet peas and everbearing strawberries need 1500-2000 foot candles and cucumbers require 4000 foot candles.[6] If these plants receive 1500-4000 lumens per square foot from free sunlight during the lunar day and just 1000 foot candles for 16 hours out of every 24 hour period from sulfur lamps during the lunar night they will do just fine.

A thousand foot candles is like a cloudy day. Although the Sun might drench the Earth with the energy of 4 MW per acre, 1000 MW per square kilometer, and 2500 MW per square mile, only a tenth of this is needed for light hungry plants like the coffee plant. A one acre garden plot in a lunar lava tube illuminated by sulfur lamps will need 43,560,000 lumens to deliver 1000 lumens per square foot. Only 460 kilowatts will be necessary for one acre if sulfur lamps rated at 95 lumens per watt are used. To illuminate a square mile of lunar gardens, 290 megawatts is needed.

This is not impractical given the intense, constant solar energy that's never obscured by clouds available by day on the Moon that can be harvested with silicon solar panels or polished magnesium solar thermal collectors and stored in the form of hydrogen and oxygen that can energize fuel cells for electricity by night. Nuclear reactors can also be used on the Moon with impunity. There is no air, no groundwater, no wildlife and no ecosystem on the Moon that could be harmed by a meltdown or nuclear waste dump. Nuclear fuel could be reprocessed and breeder reactors could be used to tap the energy of plutonium. Massive containment buildings won't even be necessary. Terrorists will never make it to the Moon and if they do they will never make it back to Earth.

Rationing nightspan lighting for plants

Although we can generate the electricity needed to furnish the crops with light, there are many other strategies to make lunar farming successful. It has been found that plants can be grown for two weeks at a time in sunlight and then put into "suspended animation" in darkness by refrigerating them for two weeks at a time. By doing this, some crops can be raised with no artificial light or power drain at all.[7] Mushrooms can be raised in the dark. Three pounds of edible fungi per square foot of garden space can be harvested every fifteen weeks.[8]

Specific Plants

Algae like Spirulina can be cultivated during the lunar day. Since blue-green algae can double its mass four times a day, in five days 100 grams of algae could reach a mass of 100 metric tons if it has enough water tank volume, minerals and carbon dioxide. It is therefore possible to grow enough algae while free sunlight is available during the lunar day to feed livestock throughout the month. Fish can eat algae. Goats and pigs will eat anything. Algae is actually very nutritious, high in protein, minerals and vitamins. Chickens might eat pellets of algae.

Mushrooms could feed the animals too. Moon dirt could be mixed with algae and mushrooms, allowed to rot and form a rich compost, and earthworms could be farmed in the rich dirt. Chickens and fish will eat chopped worms. Livestock won't need more than a few lumens per square foot to see. Fungi and worms won't need any light and algae only needs to grow by day. Clearly, a lunar diet rich in fish, chicken, eggs, pork, goat meat, goat's milk, cheese, butter and cream can be produced without artificially illuminated crops at all!

Non-vegetarian foods

Eggs and liver are rich in vitamin A, so no one will die due to a lack of carrots. Meat has plenty of B-complex. Milk contains vitamin D or people can just sunbathe for 10-20 minutes a day. Some vitamins C and E are still desired, and so is some fiber. Some wheat for whole wheat bread and dough, tomatoes, potatoes, lettuce, grapes, strawberries, cucumbers and pumpkins can be grown with sulfur lamp illumination by night or by using the nighttime refrigerating technique, which will not require any heavy machinery; we will simply turn off the heat in the garden chambers and let them cool down.

A diet heavy on meat, fish and dairy products consumed during a two-week vacation on the Moon will not irreparably damage anybody's coronary arteries. Hotel workers, miners and scientists spending a couple of years on the Moon won't die of heart disease either if they stay fit. Fish, chicken and lean goat chops might be preferable to lots of eggs, heavy cream and bacon for the health conscious Lunans.

The Moon will never support billions of people as Earth does or Mars could after centuries of terraforming, but it doesn't have to. Millions of miners, scientists, workers and tourists who are the life blood of the Moon can be supported by the underground farms in lava tubes and man-made tunnels that will someday be planted in the Moon. Eventually, craters will be domed over with giant bi-layer silicone bubbles with five meter thick water shields for radiation protection.[9] Fusion powerplants will supply electricity for the sulfur lamps and the resources of near Earth asteroids will be utilized. Subway tunnels will interconnect the domed craters. The Moon will become a fantastic playground and a jewel for all citizens of Earth, like the Great American West today. **<DD>**

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Extracting Silica from Lunar Regolith

by Dave Dietzler <pioneer137@yahoo.com>

Silicon can be extracted from lunar regolith by leaching it with hydrofluoric acid or treating it with fluorine gas to produce silicon tetrafluoride gas that can be decomposed at high temperatures to obtain silicon and recover fluorine. The silicon can be purified further by zone refining, a process that will be easier in the lunar vacuum. Large quantities of silicon will be needed for solar panels, but there will also be a huge demand for plain old silicon dioxide (silica), which composes about half of the lunar regolith, to make glass. It should be possible to take regolith that has been roasted to extract volatiles and exposed to magnets to remove iron, nickel and cobalt, and leach it with a sulfuric acid and water solution. Oxides of calcium, aluminum, magnesium, titanium, manganese, chromium, sodium and potassium will react with the acid to form sulfates. Silica will not dissolve in the sulfuric acid and it can be filtered out. Calcium sulfate is only slightly soluble and will precipitate out. Traces of chromic sulfate may also precipitate.

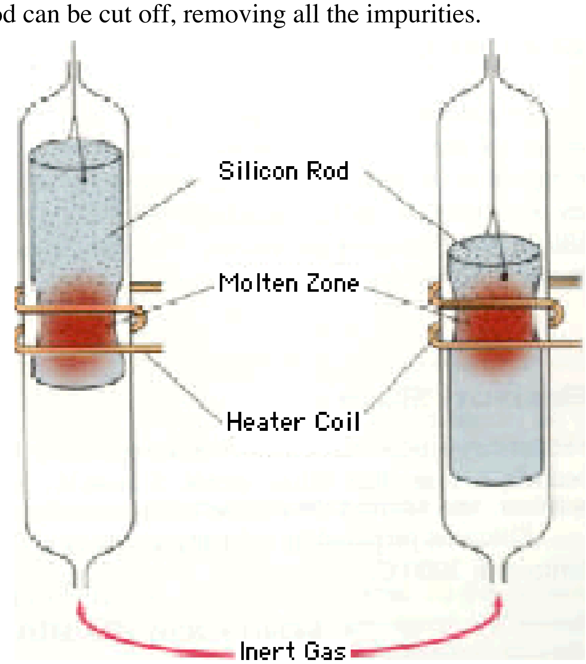
Separating the calcium sulfate ($CaSO_4$) from the silica to get a good sand for glassmaking will require some ingenuity. Molten glass and molten calcium sulfate might simply be immiscible, thereby making it possible to just skim one substance off of the other. Calcium sulfate is found in nature as gypsum. I've never heard of a glass-gypsum mixture, so it's possible that they don't blend. If glass and gypsum do dissolve together, it may be possible to take the mixture of silica and artificial gypsum "sand" filtered out of the acid solution and heat it up to 1400°-1500° C. This will melt the calcium sulfate but not the silica which melts at 1700°-1800° C. The liquid $CaSO_4$ will seep down and settle in the bottom of the vat. The silica sand can then be shoveled out and the mixture of artificial gypsum and silica at the bottom of the vat can be mixed with more iron-free regolith and water to make mortar. It may also be possible to calcine the mixture, that is to heat it to high temperatures, and decompose the CaSO4 to CaO and oxides of sulfur that can be used to restock sulfuric acid supplies.

The final strategy could be to take the mixture of silica and CaSO4 and leach it with hot water. Calcium sulfate is slightly soluble in water but silica is not. The CaSO4 bearing water will be filtered and boiled down. The steam will be condensed to get hot water that is piped back to the silica/gypsum mixture. In this way we can use the same water over and over again. My back-of-the-envelope calculations show that this will be very energy intensive. Hot water may have to be cycled hundreds of times to wash out the CaSO4. Several square miles of silicon PVs will be needed to power a system that can wash out the CaSO4 formed by treating a million tons of regolith over a period of several years! It would be wise to use waste heat from nuclear reactors to boil the water and recover the waste heat from the water condensers also for the sake of efficiency. However, a million tons of regolith is an off-the-cuff figure. I doubt that we will need the 400,000 to 500,000 tons of silica and glass that would be obtained from that much regolith. The sulfuric acid demand would also be enormous. It becomes obvious that iron and cast basalt will be our primary materials on the Moon, as these are easiest to obtain.

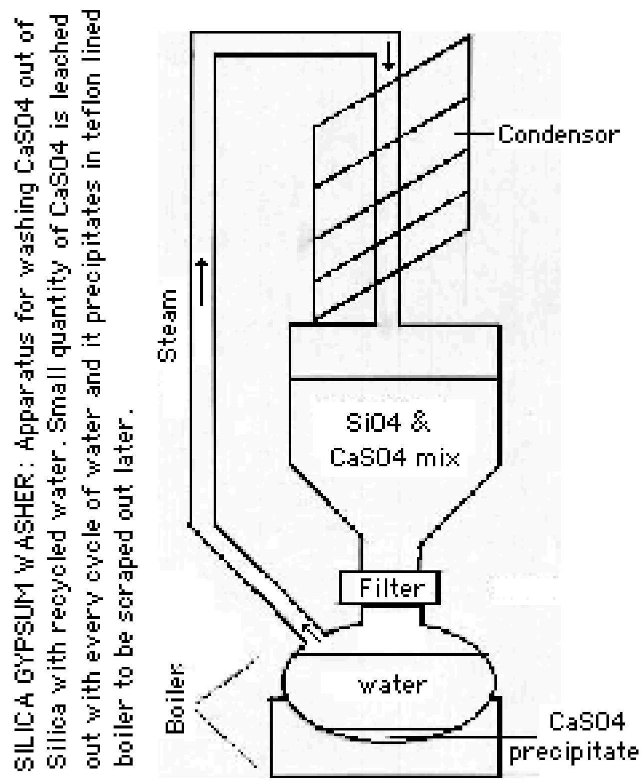
Glass made from regolithic silica might be purified by zone refining if necessary. Zone refining is usually used to produce small quantities of super pure material. In space, large scale use of zone refining should be possible. The sulfate salt byproducts of silica extraction might be decomposed in a 3000° C arc furnace for sulfur recovery. **<DD>**

ILLUSTRATIONS for preceding article:

ZONE REFINING: a silicon rod is slowly lowered through a heater coil, which melts the rod. The impurities concentrate in the melt zone that moves upward. Surface tension holds the two parts of the rod together at the molten zone. After cooling, the previously molten zone at the end of the rod can be cut off, removing all the impurities.



SILICA GYPSUM WASHER: A device similar to this could separate the SiO2 and CaSO4 formed after sulfuric acid (H2SO4) leach of regolith.



CONCRETE

A Versatile Lunar Material of Choice

by Peter Kokh

In case you haven't noticed, concrete "isn't just for sidewalks and driveways anymore." Concrete is being reinvented, brought "into the 21st Century" and reformulated for a whole host of new applications old concrete people had never thought of before.

We've all been aware of "shotcrete" for some time now. Shotcrete is a refined homogenized mixture strengthened by fiber additives so it can be pumped through a hose and sprayed on interior and exterior surfaces over attached steel mesh. Common applications are on the ceilings of lofts and industrial buildings and the inside of dome structures.

But now manufactures are using it for high end flooring, tile, shingles, textured wall panels, and more.

Concrete has these things going for it:

- it is poured at room temperatures (and below) and does not need high heat to fabricate as do glass, ceramic, and metal alloys
- it can be pigmented
- it can be stained and painted with many faux finishes to mimic other materials or with a unique character all its own
- it is an ideal for one of a kind and low quantity items and for outside the factory on site production.

Relevance for the Space Frontier: Lunar Concrete Enterprises

These "selling points" make it an attractive material for frontier pioneer entrepreneurs catering to the Lunar and Martian homestead market, as well as to do-it-yourself inclined individual homestead owners. Future Lunans will have to show considerable resourcefulness in substituting for exotic (to them) materials commonplace on Earth: wood, plastics, other petroleum-based synthetic materials.

That making items for the homestead out of concrete does not require special factory furnaces or even small house-worthy kilns, as would on site manufacture of glass, ceramic, or metal alloy items, makes concrete an option that is sure to become a mainstay. Cured and used indoors, the water in the poured wet mix is recovered to the biosphere. It can be pigmented with metal oxide powders.

With all the new recently field-tested ways to play with concrete's surface appearance, one doesn't have to "settle for" concrete. Concrete can be made to mimic ceramic tile, terra cotta, even wood (in surface texture and color at least). However, not all the new tricks being applied here on Earth promise to be applicable on the Moon!

Here are just some of what *would seem to be*

"Moon-appropriate" applications:

- tables, table tops and countertops
- contour-shaped seating surfaces & benches
- lamp bases
- planters - big, small, inside, streetside
- sink basins
- shotcrete interior finishes
- textured wall panels
- floors and floor & wall tiles
- trimwork (analogous to "woodwork")
- mantles & fireplace surrounds
- fountains & pools
- inside sculptures
- garden hardscapes
- "architectural" elements
- streetside entry trim
- streetscape sculptures
- embrasures (hold back shielding surrounding an airlock access)
- air lock entry trim
- shielding mound decorative cladding
- out-vac sculptures

Some of these items are likely to be mass produced, others custom ordered or even custom made by entrepreneurs in a shop or on site, and by do-it-yourselfers, for themselves, or as part of a "cottage industry" enterprise startup. This wide range of applications and appropriate fabrication situations makes concrete so versatile.

The Devil is in the Details

Many of the new applications for concrete involve products made by extrusion. This requires a very smooth and homogeneous mixture with considerable strength. That strength is achieved by a high fiber content. Now on the Moon, it should be no problem to manufacture both glass and steel fibers. Relying on them alone will not produce the higher qualities of the cement formulations now being widely used. For in almost all cases, here the glass fibers are jacketed with polypropylene, a petroleum-derived material that will surely fall in the exotic category on the Moon. Further, these glass/PP composite fibers are complemented by PVA polyvinyl alcohol fibers, another Moon-exotic material.

[**New tests** show that glass fibers produced in vacuum have some elasticity. This may solve the perceived problem.]

In addition to this fiber content, most extrudable concrete mixes substitute "Illinois Fly Ash" for up to 70% of the cement. Cement is a calcium based material that will be fairly easy to produce in large quantities on the Moon. As for the ash, a substitute that comes to mind is the fine powdery component of regolith, likely to be sifted out (and thus available as a homogenized byproduct) of most lunar regolith processing operations.

However, particle grain-size isn't the only thing that matters. Particle shape comes into play as well. While the irregular jagged shape of lunar "fines" gave the lunar simulated concrete prepared by Dr. T.D. Lin in the 1980s great strength, "twice that of everyday terrestrial concrete," that very same asset becomes a liability when it comes to extrusion of the liquid concrete mix. Illinois Fly Ash (IFA) has a spherical particle shape that makes it slippery, much like graphite powder. It should be possible, however, to further separate the lunar regolith fines for their high glassy spherule component. These spherules have been produced by the high extremely concentrated heat of impact in eons of constant micrometeorite bombardment.

But what about the fly ash chemical character - the regolith fines and glassy spherule inclusions should both be rather inert. According to the Fly Ash Resource Center [www.geocities.com/CapeCanaveral/Launchpad/2095/flyash.html] fly ash is "the finely-divided CCB [coal combustion byproduct] collected by electrostatic precipitators from the flue gases." It has a high 20% carbon content.

> "Using coal fly ash conserves energy by reducing the demand for typical pavement materials such as lime, cement and crushed stone, which take energy to produce. Each ton of fly ash used to replace a ton of cement, for example, saves the equivalent of nearly one barrel of imported oil."

The most important fact of life for would be pioneers of lunar industries to keep in mind at the very forefront of consciousness can be summed up in this one phrase: "The Path Not Taken." Here on Earth, when R&D discovers something that works very well, further experimentation on all other lines that has not yet produced equivalent promise, is halted. It's simply a matter of conserving research and development dollars. Let's translate that into a "Space Frontier Pioneering Guiding Light Principle."

> That R&D has been halted on a line of experimentation, doesn't indicate that there is nothing promising to be gained from pursuing it further.

We need to find people in cement industry R&D laboratories who are willing to find a way to sneak in some off-line experiments using strictly those ingredients we can produce or simulate on the Moon at acceptable energy and source material costs. Make no mistake, without that research, concrete will still be a mainstay building material on the Moon. But barring success in formulating lunar-appropriate extrudable formulations, some of the new wonder applications we are seeing here on Earth in the 90s and the current “double oughts” [as the first decade of the 20th C was called] will not be practical on the Moon. And that would be a shame.

Environmental Friendly Concrete

For the sake of argument, let’s say that the suggested research is done and turns up nothing promising. Concrete would still be a space frontier workhorse even with out extruded products, without shotcrete. It can still be poured and molded and pigmented and textured.

But especially interesting from the environmental point of view is that concrete accepts aggregate inclusions: pebbles, stones, gravel - we all know about that. But if that is as far as your familiarity goes, you’re no longer up to date. A California firm, Syndesis, [www.syndesisinc.com] has pioneered using the detritus of civilization in lieu of ‘normal’ aggregate:

> Syndecrete® is a restorative product, reconstituting materials extracted from society's waste stream to create a new, highly valued product. The advanced cement based composite contains natural minerals and recycled materials from industry and post consumer goods which contain up to 41% recycled content. Such materials include metal shavings, plastic regrinds, recycled glass chips and scrap wood chips to name a few. These materials are used as decorative aggregates, creating a contemporary reinterpretation of ... terrazzo. ... Syndecrete® uses no polymers or resins. ... a solid surfacing material which provides consistency of color, texture, and aggregate throughout ... less than half the weight with twice the compressive strength of normal concrete. Surfaces can be ground, polished, or textured to expose the natural porosity and aggregates. Form or mold surface finishes allow exacting detail, from wood grain to glass.

What is exciting to me about this is it will help minimize the need of lunar civilization to follow the sorry steps of their terrestrial ancestors “from mine to landfill” by creating an avenue, particularly attractive to entrepreneurs, to use the kind of manufacturing and domestic usage waste like that cited above (less the plastic and wood!) to make valued consumer goods for total less expenditure given to source materials. These inclusions have character of texture and color and visual interest, for which the energy has already been spent. Reusing that spent energy in this way will be one way to make lunar settlements more efficient and minimize what I call “throughput” - the percentage of, and rate at which, raw lunar materials pass through the lunar consumption system to end in some lunar crater landfill.

Concrete is a material with much promise for Lunan contractors and entrepreneurs and consumers. In the newborn space frontier tradition of spin-up (not off) entrepreneurs here can help pioneer the road, for profits here and now.

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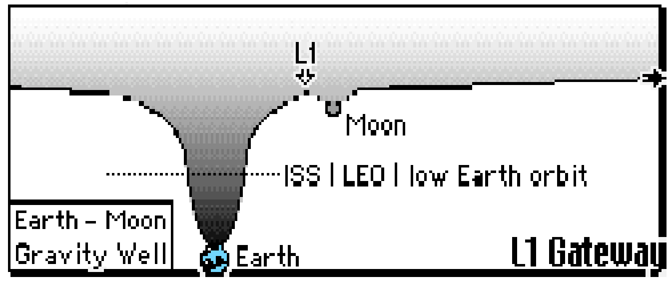

Expanding Manned Space to the L1 Gateway

Robert A, Heinlein is often quoted as saying “once you are in low Earth orbit, you’re half way to anywhere.” He might have gone on to point out that once you are at L1 you are 90% of the way to anywhere. In our illustration, L1 perches on a “gravity divide” hillcrest, equally handy to the Moon and Mars. For more =>> *below*.

MOON POWER

Dave Dietzler <pioneer137@yahoo.com> 9/22/2002

The Global Warming Challenge

Energy from the Moon is vital to the world's future. Dwindling oil supplies, global warming, pollution, coal burning and strip mining, nuclear waste and the threat of melt-downs cannot simply be ignored. Winds, tides, geothermal, dams, OTEC, ground based solar, biogass, high-temperature superconducting cables, switching to household fluorescents and LEDs, thicker home insulation, and conservation can help, but they cannot solve the problem entirely. World demand for electricity due to rising standards of living worldwide will increase many-fold. Fuel cell powered cars as well as heating that is now provided by shrinking natural gas supplies will increase the demand for electricity even more.

Fusion Power?

Fusion may be the answer. The temperatures required for fusion have been produced. To achieve the necessary plasma densities and confinement times in TOKAMAKS may be as simple as using larger, more powerful magnets made of YBCO cooled by liquid nitrogen. The strength of the magnetic field is central to confining the plasma, so larger magnets carrying higher currents are the way to go.

Fusion reactors will be enormous machines. The IETR (International Experimental Thermonuclear Reactor) will stand three stories tall and have magnets that amass 10,000 tons, but it will only be a demonstration reactor capable of generating 500 megawatts. A TOKAMAK that can crank out 1500 MW would be even more gigantic. Obviously, it would also be expensive. The IETR budget is several billion dollars. If deuterium and tritium are fused, neutrons and radioactive waste will result. Although the quantity will be miniscule compared to the waste from fission reactors, there will be problems with reactor materials becoming radioactive and giving off heat. This could limit the lifetime of these huge and expensive TOKAMAKS.

Lunar Helium-3 to the rescue

Helium 3 from the Moon is the solution. This substance when "burned" with deuterium or fused with itself produces virtually no neutrons. A fusion reactor that can use helium 3 will have even more massive magnet assemblies than a deuterium/tritium fusion reactor because helium 3 plasmas require higher temperatures to ignite and are more difficult to contain. Laser fusion reactors might someday be less massive that TOKAMAKS, but laser fusion lags behind magnetic fusion.

The Solar Power Satellite option

If a fusion solution does not turn out to be feasible from both an engineering and economic standpoint, solar energy is our world's only hope. As O'Neill made clear, the best place to base solar power collectors would be in GEO where the Sun shines 24/7 unobscured by clouds, and from where power could be beamed down via microwaves. Lunar materials would be the key to this enterprise.

Industrial Operations on the Moon needed

Since we don't know if fusion will ever pan out, but there is no theoretical reason SPSs would not work, it makes sense to industrialize the Moon now. Decades of development on the Moon may be needed to do the job. If HE-3 fusion is commercially possible and profitable, we will still need SPSs. To power the world of the 21st century with helium 3, about 300 tons a year would be needed, and this would entail the mining of 30 billion tons of lunar regolith every year. That might be prohibitive.

O'Neill's original 5,000 MW turbogenerator SPS would only amass 80,000 tons and last for decades, perhaps centuries. The aluminum reflectors and structure would not corrode at all in space; only the turbines and electronics would need replacement. Since inert helium would probably be the working fluid, the turbines might run for over 50 years as the TVA dam turbines did before first-time overhaul.

An SPS should be a good long term investment. To produce as much energy as 300 tons of He3- 5,700,000 MW years, 1140 five gigawatt SPSs spaced 145 miles apart in GEO are needed. About 91 million tons of material, mostly aluminum, would be needed to build these powersats. Obviously, we won't have to do as much Moon mining to build these SPSs and it is a one time or once a century job.

SPS Limitations

Cities in the arctic regions might still get along better with helium 3 fusion*. Microwave beams from GEO powersats would have to pass through more atmosphere to reach receiving antennas in the higher latitudes. Beams would spread out at the more oblique angle of the Earth's surface in those regions and much more rectenna area would be required.

Fusion reactors would also provide the benefit of waste heat that could be fed through underground steam loops to buildings in arctic cities. Since a fusion reactor cannot explode or melt down and HE-3 fusion will generate virtually no radioactive waste, the fusion plants could be located in the hearts of arctic cities. The best possible future would be one in which SPSs and He3 from the Moon allowed the generation of vast amounts of clean energy. The Moon is worth trillions of dollars yearly, and the preservation of the Earth's biosphere.

* 150 Ton Magnet pulls World toward new energy Source www.spacedaily.com/news/energy-tech-02p.html

* [Editor: another solution: use SPS rectennas in the tropics to power electrolysis of sea water to produce Hydrogen shipped to the arctic as a power source.]

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Lunar Cement & Plaster

Dave Dietzler <pioneer137@yahoo.com>

Gypsum as a byproduct of Silica production

In the process of leaching silica out of regolith with sulfuric acid there will also be the formation of barely soluble calcium sulfate. Calcium sulfate is also known as gypsum when found in nature or plaster of Paris when roasted and dried. There are 80,000 tons of calcium in a million tons of regolith. Without going into the details of stochiometry, this is enough to make 272,000 tons of artificial gypsum. We could plaster a lot of porous walls in lava tubes with that and add a coat of sodium silicate based paint. The CaSO4 powder can be wetted to make a slurry, laid down on paper, coated with another layer of paper, allowed to dry and the result is wall board, also called sheet rock. Besides plaster, CaSO4 is used as a soil conditioner and Portland cement is made with about 5% gypsum.

The problem is separating the CaSO4 from the silica. Since about 0.66 grams of calcium sulfate will dissolve in a liter of water, it may be possible to use recycled water and waste heat from nuclear reactors to wash the gypsum out of the mix to get a pure sand for glassmaking. This will be slow and energy intensive. Fortunately, the stuff is actually where we want it to be-mixed with silica-for cement making. We will need far more cement than plaster or glass to make settlements in lunar lava tubes. From Van Nostrand's Scientific Encyclopedia, 8th edition, we find that:

"In the Muller-Kuhne process [for making cement], gypsum is mixed with clay and silica in quantities necessary to make cement, along with coke to reduce CaSO4 to CaO."

During the roast the carbon reduces the gypsum in the mixture to lime (CaO), the necessary ingredient for mortar and cement; and sulfur dioxide, carbon monoxide and CO2 form. The SO2 can be converted back to sulfuric acid and the CO & CO2 can be reacted with hydrogen in a Sabatier reactor to form methane and water. Methane can be pyrolized to recover carbon and water electrolyzed to recover hydrogen-or just left as is because water rather than hydrogen will probably be what we need-carbon recovery is the main thing. We will already be doing this very same thing in the process of aluminum refining to recover carbon from electrodes that burn up during electrolysis, so we can use some of the same equipment for both jobs-two birds, one stone. A mixture of silica, lime, regolith, water and a little CaSO4 should make decent cement.

Getting the needed Reagents

So where are we going to get all that hydrogen and sulfur for sulfuric acid to make the stuff? Other sulfate compounds formed when the lunar dirt is leached will be decomposed to recover the sulfur, and water that forms during the reaction of oxides with acid will be boiled off and saved. If we make 272,000 tons of $CaSO_4$ we will use up 64,000 tons of sulfur. At 500 ppm, that much sulfur could be roasted out of 128 million tons of regolith during He 3 mining, or about enough to produce one ton of helium 3. We will need 196,000 tons of sulfuric acid containing 128,000 tons of oxygen and 4,000 tons of hydrogen.

That much oxygen could be extracted from 320,000 tons of regolith and the hydrogen could come from polar ice or be roasted out of 100 million tons of regolith. We can recycle the hydrogen by using water that forms from the reaction: $CaO+H_2SO_4=CaSO_4+H_2O$ As long as we are producing fresh sulfur and oxygen to make sulfur trioxide, SO_3, which then reacts spontaneously with water to make sulfuric acid, we're in business and we don't have to worry about mining so much hydrogen, even though we will mine every bit we can for its many uses. Most of the gypsum will be reduced to lime for cement and the SO_2 recovered to keep up acid supplies.

Cement rather than plaster could be used to coat lava tube walls. Cement could be poured to make smooth floors, solid walls, swimming pools, fish pools, furniture, etc. Calcium sulfate washed out of the silica mixture could be reduced with carbon to get lime (CaO) which can be mixed with sand and water to make mortar for stacking cast basalt bricks. Lime can also be used for white wash and glass-making. It can also be reduced with aluminum to get pure calcium metal for highly conductive cable.

Finding sedimentary gypsum deposits on Mars

We might find natural sedimentary deposits of gypsum on Mars, but on the Moon we will have to make the stuff. Plaster is used for tooth impressions, casts for broken limbs, pottery, lamp bases, molds for casting nonferrous metals, patching and grouting compounds, pharmaceutical-tablet diluent and even tofu. As for the sulfates left over after filtering out the silica/gypsum mixture and boiling down the liquid, I leave the task of separating that mishmash to the future. Any suggestions?

For those who want to see the math:

Weights: Ca=40 S=32 O4=64 -- $CaSO_4$=136 SO_4=96

80,000 tons Ca/x = 40/136 x=272,000 tons $CaSO_4$

272,000-80,000=192,000 tons of SO_4 32/96= x/192,000 x=64,000 tons S
192,000-64,000=128,000 tons O since regolith is 40% oxygen by weight:
128,000/0.40=320,000 tons regolith

H_2SO_4=98 x/192,000=98/96 x=196,000
196,000-192,000=4,000

40 ppm H, 40 tons hydrogen per one million tons of regolith

100 million tons regolith = 4,000 tons hydrogen and one ton He3

<DD>

Expanding the Manned Space Envelope

The Earth-Moon L1 Gateway

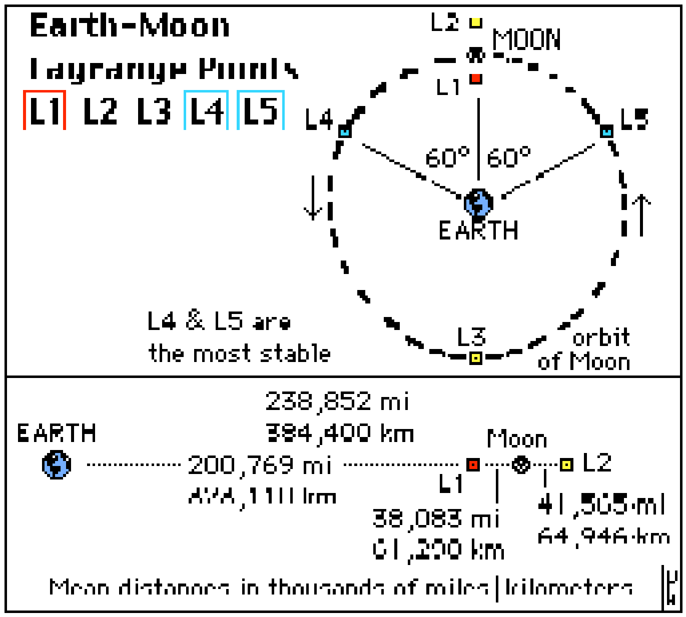
www.space.com/news/beyond_iss_020926-1.html
NASA's New Plan for the Moon, Mars & Outward *and*
www.space.com/businesstechnology/technology/moon_next_020923-2.html (*)

Article & Commentary below by Peter Kokh (*)

"NASA is developing a progressive plan for placing humans back onto the Moon. NASA Exploration Team (NExT) members at the Johnson Space Center have scripted a breakthrough strategy ... [that] makes use of existing launch capability and existing technology to establish a staging point at a so-called Earth-Moon Lagrangian Point, L1.

"Here's why L1 is important: In each system of two heavy bodies (the Sun and Jupiter, or Earth and its Moon) there exist five theoretical points in space at which a third and small body, under the gravitational influence of the two large ones, will remain approximately at rest relative to them.

"From the Earth-Moon L1 point [between the Earth and the Moon], a window to any spot on the Moon is reachable with minimal rocket energy."



Note: the distances given between L1 and the Moon and L2 and the Moon are calculated from the Moon's center. For mean distance to the nearest point on the Moon's surface, subtract 1,089 mi = 1,728 km.

A Plan in its Infancy

NASA's Exploration Team [NExT] has done little more than identify the need, and the location where that need can best be met. Any plan to build and erect another "Space Station" - this one at the Earth Moon L1 Lagrangian Point Gateway would have to be approved by Congress in order to become a budget item. There is probably no reason to begin planning implementation strategies, until NASA is ready to talk to Congress about the idea.

What it does and does not mean

That the L1 point is ideal as a gateway for flights to anywhere n the Moon's surface, NASA's interest in this gateway does not mean that the agency has made a decision to return to the Moon, over, or before, sending humans to Mars. The beauty of the L1 Gateway is that it is also an ideal spot for staging missions to Mars. In other words, the establishment of an Earth-Moon L1 Gateway would enable all competing scenarios for the expansion of the Manned Space Envelope beyond low Earth orbit.

Usefulness of a Lunar L1 Gateway Station

(a) Research & Logistics

- testing the radiation environment in high Earth orbit (HEO) and techniques for maintaining a habitat environment safe for humans beyond the Van Allen belts - Apollo astronauts have been beyond that protection for no more than several days per mission.
- teleoperation via relay of SPA (South Pole-Aitken Basin) return sample mission (MMM #157 p. 4) and other surface probes
- teleoperation via relay of Farside radio telescope

(b) Manned Lunar surface Operations support

- teleoperating prospecting & mining equipment in surface locations remote from manned outpost
- Staging | rendezvous for maximized efficiency configuration for space to lunar surface ferries
- a cryogenics fuel depot to provide braking fuel for craft bound for the lunar surface at much less cost than bringing that fuel all the way from Earth's surface (LUNOX: liquid oxygen produced from processed moondust) | LH2)

(c) Mars Mission support

- ideal quarantine site for Mars Sample Returns
- assembling larger Mars-bound spacecraft in an environment free of orbital debris at a facility that needs much less station keeping fuel than in low Earth orbit with more frequent & wider launch windows to Mars
- refueling (topping off) Mars-bound missions with lunar liquid oxygen and possibly hydrogen brought up from the Moon's surface at a fraction of the fuel cost of getting them all the way "up the hill" from Earth

That such a gateway could enable and facilitate so many space mission/manned mission options, makes it a win-win idea certain to gather much more widespread (if less enthusiastic) support than either a Moonbase or Marsbase proposal could garner. This very aspect of "positive indeterminacy" (my terms) makes it a safe proposal for Congress persons to get behind. It pushes our future without making premature choices, leaving those choices to sort themselves out on their own merits

The Space Frontier Foundation has already issued a supporting policy statement. Our recommendation is that the National Space Society and the Moon Society do the same.

- **Our suggestions for go-withs and phase-ins**
  - L4/L5 relay sats - small Data Relay Satellites at the Earth-Moon L4 and L5 Lagrange points would facilitate dedicated relay covering the farside flanks of nearside, reaching 60° past the east and west limbs of the Moon. They could be equipped with simple Dust Counters to qualify the "environment" of these possibly very dusty "Sargasso Sea" regions. Weight allowances and commercial sponsors willing, they could include teleoperated Amateur Telescopes to train on this beyond the limb reasons for the first time.
  - An Unmanned Help-Yourself Fuel Depot be established first: this would be consist of a LUNOX tank farm to allow less expensive Earth-Moon and Moon-Earth flights. Attached station-keeping* thrusters would tap this fuel supply to keep the fuel depot "at" L1 as this position is not as stable as the L4 and L5 areas.

    * [L4 an L5 can be described as "bowl-shaped gravity valleys" - any deviation from the center causes a drift back to the center. However L1 (and 2 and 3) are better described as "saddle valleys" with the saddle perpendicular to the Earth Moon axis. Any movement to the side causes a drift back to the center, whereas any movement in the direction of the axis will keep gaining momentum and send the object on a collision course with Earth or the Moon as the case may be.]
  - A Tool & Common Parts Crib could be added
  - A Habitat Module could be added which would be for the use of personnel in transit and occupied only while a manned ship is docked at the station
  - Crews could arrive at L1 a proper amount of time before the start of temporary assembly jobs, e.g. of larger ship consists headed out to Mars, returning to Earth when the job is done.
  - In other words, this Gateway need not start out as another permanently occupied Space Station. This more modest, just in time staffing proposal would be far more likely to be approved by the keepers of the purse strings.
- **Implications for a Free Enterprise venture to open the Moon to resource-using settlement:**
- If the L1 Gateway is pursued in the form of a robotic facility open to use by all who pass that way, it can serve the cause of a commercial lunar overture just as easily as that of a NASA-led manned expedition to Mars.
- NASA has been bragging, a bit prematurely we think, about having commercialized the International Space Station. What NASA seems to understand by "commercial" is not the same as what most proponents of free enterprise access to space mean by it. But by careful and judicious writing of the enabling legislation, something with which it behooves all of us to be involved, we can end up with a "positive-neutral" facility genuinely helpful to all types of ventures. We need legislation that does not pick winners and losers, which does not exclusively suit the world view of a socialized space program.
- NASA does have a role, valued by all and not in dispute, to play in opening the Moon, of course.
  - First we need a number of follow up orbiter-lander missions whether designed by NASA or elsewhere but flown as NASA Discovery missions:
    - □ South Pole Aitken basin sample return
    - □ "ground truth" polar lander probes to quantify and qualify potential ice resources

- □ Oregon L5's proposed Lunar Lavatube Locator mission
- Beyond that it will be largely a NASA task to set up optical, radio, and other astronomical observatories on the Moon. If NASA opens the door to space rather than keep posing as the door, the L1 Gateway could be, in Martha Stewart's words, "a good thing." **<MMM>**

Online Reading:

Strategic Considerations for a Cislunar Space Infrastructure by Wendell Mendell

http://ares.jsc.nasa.gov/HumanExplore/Exploration/EXLibrary/DOCS/EIC042.HTML

[as a staging point for Mars missions, ISS] "has features which diminish usefulness and longevity, thereby limiting its ability to support long term piloted spaceflight. These include:

- "Lunar/Mars launch window constraints: Launching vehicles to the Moon and Mars from a LEO "shipyard" is complicated by continuous changes in the alignment of the space station orbit relative to the desired trajectory [limiting] the number and duration of available launch opportunities.
- "Orbital debris: Artificial space debris is an increasingly significant threat to LEO facilities as space traffic increases. Space Station Alpha will carry rockets for collision avoidance and a substantial mass of shielding.
- "Atmospheric drag: LEO stations pass through the outermost reaches of Earth's atmosphere, so suffer drag and eventually decay from orbit and burn up if not periodically reboosted."

The Lunar L1 Gateway

Martin Lo/Shane Ross (Space 2001, Albuquerque)

http://www.cds.caltech.edu/~shane/papers/lo_ross_2001_abs.html [abstract] ".. natural Interplanetary Superhighway System .."

Some Past L1 Station Proposals

The idea of a Gateway Station at Earth-Moon L1 = Lagrange Point 1, a semi-stable "gravitational divide" 84% of the way from the Earth to the Moon, is not new. To many space transportation system architects, it's a natural concept.

"the Earth-Moon L1 point is the physical entry point into the lunar environment."

- Badri A. Younes/GSFC

An L1 station would serve as end terminal for Earth-Moon ferries that remained in space all the time, never touching a planetary surface. On our end, a space station in low Earth Orbit acts as a depot transfer station for people coming from/ returning to Earth's surface on a space shuttle of some kind. On the other end, an L1 station acts as a depot for people getting off of shuttles coming up from the Moon's surface, or getting on those same shuttles for the trip down. In between is the domain of the ferries -- and someday, the liners.

This was the original Von Braun idea, but we could never have "won" the "race" to the Moon if we had stopped to build either or both depots. So NASA designed the Apollo command module as both the ferry and as the return Earth shuttle; and the Lunar Excursion Module as the 2-part low lunar orbit to lunar surface shuttle.

A consensus decision was made to put any further exploration of the Moon on hold until these transportation nodes were in place. In retrospect, that was a flawed decision. There is such a thing as "just-in-time" infrastructure. We don't need an O'Hare field, much less a Kansai International - if all we are flying are Ford tri-motors. That's interesting topic for another issue

. Those of you who have seen the 1991 Made for- TV Disney/Zlatoff film Plymouth about a pioneer settlement on the Moon engaged in Helium-3 harvesting, will remember that the last wave of settlers took one ship out from Earth, then transferred to a lunar shuttle at the L1 depot some 38,000 miles Earthward from the Moon.

In the Kubrick/Clarke epic 2001 (1968) : a Space Odyssey, Dr. Heywood Floyd takes a shuttle up from Earth to a "real" spinning space station in Earth Orbit, then an Earth-Moon ferry, and finally arrives on the Moon aboard a large lunar shuttle.

The whole point of having a pair of gateways is to gain economy from allowing Earth surface to orbit craft be specialized precisely for that task, Lunar surface to orbit craft be specialized for that run, and to use ferries designed to spend their entire lives in space to economically transferring people in between the two gateway depots. Yet, until the traffic warrants, the bottom line may favor shortcuts. We'll get our L1 gateway depot in time, but why wait to get started? - PK

A Pause for Inspiration: Quotes worth Pondering

"The best way to predict the future is to be busy creating it.

"The Best Way to Predict the Future is to Invent It!"

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

-- Kraft Ehricke

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

The Earth receives only one-half of
one billionth of the Sun's radiant energy.

Measure a man (organization) by
the opposition it takes to discourage him (it)

Judge a man not by where he has come from,
but by where he is headed toward.

Always listen to experts.
They'll tell you what can't be done and why.
Then do it. - Robert A. Heinlein

We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time.

- T. S. Eliot in "Four Quartets"

Meandering through the Universe

A Column on the Cooperative Movement on the Space Frontier © 2002 by Richard Richardson

Larry Jay Friesen's article in the June MMM #156, "Crop Selection Criteria for Lunar Settlements," really fired up the gray cells! This month I would like to continue the discussion on the slightly more general topic of plant selection for space locations.

We need to take plants with us to space. Therefore, we need to be conducting intensive research into just what our needs will be, which of our needs can be met by on site agriculture and which plants, group of plants, and/or eco-subsystems can best meet those needs under the conditions available at specific space locations. We also need to be giving attention to the problem of making the best possible conditions available for those agricultural species at those specific locations.

Plant/Crop Choice Considerations

Until technology which is still in the realm of science fiction comes along and changes the fundamentals of space transportation, we should not be wasting much time planning for extensive trade of any essential commodity. People will die ... whole communities will fail ... if we place our Faberge eggs in that basket. By that I mean, if we leave a space settlement dependent for its survival on the vagaries of technology, orbital mechanics and business politics, labor politics, government politics, terrorism, economic conditions, etc., then we not only set ourselves up for tragic failure, but for a failure which could set space settlement back generations.

Here is my brainstormed, prioritized list of considerations for selecting species for space agriculture, not just crops:

1. Unique source — Is this species the only one viable as an on site source for a critical commodity?
2. Multiple usefulness — Can the species be used as a source for more than one critical commodity? (usefulness for higher priorities weighted more)
3. Viability — How difficult is the species to grow and harvest/use? All things equal, are there better species?
4. Obtainability — How easy/difficult/expensive is it to obtain the species (here on Earth) in necessary quantities in preparation for deployment to space? And how expensive and/or difficult will it be to transport sufficient numbers of the plant to the space settlement?
5. Food production — a) quantity, b) specific nutritional contribution
6. Waste recycling
7. Toxin sequestering or neutralization
8. Source of necessary medical chemicals
9. Source of raw materials for industry
10. Source of scent — For "pleasure" use as well as to help cover unpleasant smells.
11. Pleasant (or useful) in color, texture, or other characteristic
12. Usefulness to domestic and micro businesses

Although I have used the word "plant," we also need to be researching the roles played by microbes, fungi, algae, and some small animals also.

This is a very complex problem, but it is one which we can begin sorting out Now! Unfortunately, most space enthusiasts don't realize what a pivotal priority it is nor how amenable to research. The bottom line is that opening space to settlement depends on space agriculture. Fortunately, a lot of absolutely fundamental research can be done now, by anyone, requiring nothing more than a little ingenuity and diligence and the willingness to share results so it can join the body of knowledge available for use.

Hydroponics vs. Soil Farming

And now the question of whether 'tis better to use good old fashioned soil or ride with the hydroponic wave. Actually, this question has already been settled. It would be inappropriate to grow everything hydroponically. A question which makes more sense concerns which species should be grown in soil and which should be grown hydroponically.

Even if most of the large scale production agriculture seemed best suited to hydroponics there are serious drawbacks to that approach. Hydroponics are susceptible to the quick and easy spread of disease throughout the system requiring significant preventive measures such as adding various chemicals to the water (which cost money and can pose various threats), occasional thorough cleaning, inspection of hardware, etc.

On Earth this is not as critical because, if there is a problem, a crop can be discarded. At worst, a production facility can be closed or the whole business can fail. No, one's life need be lost. But in space a lot of lives might very well depend on the reliability of agricultural production. Even aside from questions of life or death, a major business failure at a space settlement would be too momentous a proposition to take any unnecessary chances with. Also, setting up a hydroponic system extensive enough to provide the majority of the agricultural needs of a whole space community would almost certainly cost more than an equivalent soil based approach and probably be dependent on Earth sourced replacement parts for a long time.

On the other hand, soil based agriculture tends to be quite resilient, modular, requires fewer non-local components and is easier to apply to multiple simultaneous utilizations. Both alternatives require the addition of nutrients, but a soil based system can be designed such that various species of plants and soil fauna work together to provide each other nutrients, as well as disease and pest control, thereby saving money and reducing the risk of environmental contamination from the application of additives. Soil based agriculture can serve as the foundation, and, perhaps, almost the entirety, of an efficient, reliable, and even attractive life support system. Also, the fairly well rounded ecology necessary for a thorough and productive soil based agricultural system provides a solid foundation for the supply of pharmaceuticals, the removal of toxins from the environment, tourism opportunities that would otherwise not exist, the supply of arts and crafts materials, arts staging locations, stress reducing environments ... and whatever else local innovators might dream up. In addition to all of that, there is the significant plus that it is far less susceptible to sabotage, accident, and technological failure. There is just no alternative to soil based agriculture as the core component of sustainable self sufficiency ... though hydroponics will still have a role to play, too.

The knowledge, techniques, and any products which would result from research and development in this area would be very valuable — not only in space, but here on Earth, as well. Because they would be so valuable, it will be necessary to secure permanent legal access to them lest someone secure those rights for themselves and legally deny them to others.

The Open Source Philosophy

There are two philosophies to chose from here. The traditional one is to legally secure *exclusive* ownership before anyone else does. But that is hardly better than someone not interested in space sequestering those rights. Alternatively, it would be possible to take the "open source" route. "Open source" makes the commodities in question available to all (like a public domain vegetable, for example), and specifically prohibits exclusive ownership and exclusive marketing. Also, although end users may freely make any changes or additions to the commodities in question, they may not market the product with such changes or additions unless they are placed under the same open source license *and* are approved by an authorizing committee. That may be a little confusing but all it means is that the knowledge, technology, techniques, products (or whatever) may be freely studied, duplicated, marketed, bundled, etc. — which allows anyone to learn about, experiment with, make improvements to, or base a business on the items in question. But what they cannot do is prevent anyone else from having the same freedom. This facilitates widespread distribution. Widespread distribution of the knowledge and use of space technology gets us closer to being a spacefaring race.

But if exclusive ownership of resulting commodities is prohibited even to the developers, then how are they supposed to support their work and generate their take home pay? By selling the secondary commodities associated with the fruits of the research and development. The more widespread the distribution of the primary commodities (say a new technique for making fine grained, nutrient poor soil more fertile, a new hybrid plant, or the details of an effective life support system), the more demand there will be for associated goods and services. Instead of excluding others from access to the core commodities, the developers (and others, if they have the expertise) could market things like consulting, education, individual plants (in the same way a grocery sells a public domain vegetable), agricultural products for use here on Earth (if any result from the research, and it's likely they would), experiment and educational kits, as well as LSS services such as design, maintenance, upgrading, and so on.

NASA and others would be interested in these products and services in the near term, if anyone had them to sell, that is.

There's money to be made from research and development in space agriculture and we can't have space settlements without it. Now would be a good time to start serious work. **<RRR>**

[Editor's Comments:

The plusses I see for hydroponics are these:

- control
- higher yield in less space

One must concede that the latter point is an important one, but primarily so in the present situation: all pressurized volume is manufactured on Earth and shipped to the frontier. But we are not likely to expand beyond a first small outpost so long as that continues to be the case. *So it is moot.*

Yes, if inflatables are introduced, that will provide more elbowroom, especially for activities like agriculture, with the inflatable pressure hull still being manufactured on Earth and shipped to the Moon or other space destination. In a past issue, we indeed talked about "Moonbagel Agripods" - inflatable torus structures where the routines of agriculture could be handled by robotic equipment which would literally make "the rounds" over and over, changing operations each pass.

In itself, a larger inflatable structures could serve either farming format, but the availability of more space for essentially the same buck would begin to tip the scales towards geoponics at least for those types and varieties of plants which seem to do better in soil. Once we start to manufacture pressure hull modules on location with lunar materials, the cost per square meter of pressurized space will drop.

Regolith "as is" is not ideal. We'd want to sift out the powdery fines that would clog drainage and keep the soil too wet. Heating the sifted soil a couple hundred degrees would transform a fraction of it into nutrient holding zeolites. The resulting soil would be better buffered and supply most of the nutrients that must be imported for hydroponics. - PK]

A Pause for Inspiration:

More Quotes worth Pondering

Vision without action is just a dream
Action without vision is just activity
Vision & Action together can change the world
Absolute faith corrupts as absolutely
as absolute power.
- Eric Hoffer

"I believe that from the long straight lines,
severe angles, and cracked surfaces, that
Europa seems to be populated by frustrated
workers from the California Department of
Transportation (CalTrans)."
- Arthur C. Clarke

Be concerned not with what others have
failed to do. That is beyond your power to
change. Be concerned rather with what you
have failed or might fail to do. Then the
world will be all right.

As insignificant as each of us
may seem to be in the scheme of things,
the future becomes history
through the extrusion of individual acts.
Each of us makes a difference
one way or the other.

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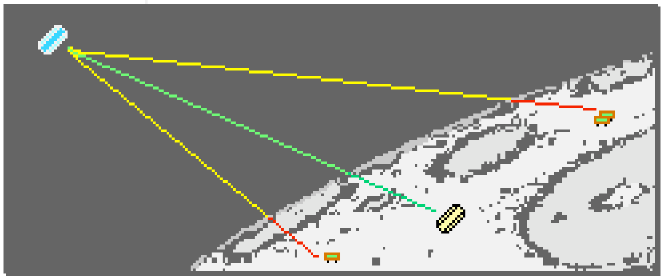
[This issue, we changed our fonts to **Gadget** & Comic Sans]



Upper and Lower Moonbase

In last month's issue, we explored NASA's recent resurrection of an old idea, a manned space facility at the Earth-Moon L1 Lagrange point. This month we see how it could logically develop on a "just-in-time" schedule, and work to accelerate, rather than delay, the expansion of surface activities. That's the way it would be done *if* business and industry is in charge. =>> *below*.

In FOCUS:
Killer Asteroids vs. Killer Debris

Editorial by Peter Kokh

Size is sexy, catastrophe is sexy. The threat of killer asteroids gets good press and sells movie tickets. And yes, the danger is real. However it is also statistically remote. Space debris is peanuts. Who cares? It poses no problem to the Earth.

Yet there are ample grounds to suspect that in the next century, which is what we should be more concerned about, it is perhaps a million times more likely that a Shuttle Orbiter or the International Space Station itself will be fatally compromised by debris impact than that a sizable astrochunk will strike a killer blow to the Earth itself. "So what?," you say. "No comparison!"

That depends on the consequences. There are many interests and causes that compete for attention with space development, and a mortal blow to the heart of manned space operations could just mean the end of the Space Age, for now. Anyone who thinks such a hiatus would be brief should consider how long the hiatus in manned lunar missions has been. Indeed, the time path from Kitty Hawk to Tranquility Base may prove shorter than that from Apollo 17 to the next manned Moon Landing.

And were that to happen, a debris-caused halt to manned space operations, what would happen to our still-on-the drawing boards "Planetary Defense Systems?" Those who are serious about asteroid impact threats should be serious about keeping the door open for manned space operations. Space Debris could close that door.

The most promising space development to come may just be space tourism. But nothing could more effectively foreclose on those dreams than uninsurability due to escalating danger from space debris. So Space Tourism advocates ought also to be concerned about debris.

The sad thing about space debris is that it is unnecessary. The overwhelming majority of space debris items are the result of the traditional western refusal to interiorize life-cycle costs. It is cheaper to throw something away, to jettison something, than to dispose of it properly. It is cheaper to make it someone else's problem. While it may be true that Russian space missions are dirtier in the debris they scatter, it is only a relative difference and we have no cause to be proud.

What we propose is a series of international workshops, each to zero in on a different source of space debris. When all the workshops have reported their findings, another series of workshops can begin to look at commonalities and where problem areas impinge on one another. Finally the time may be ripe for an International Conference on Space Debris charged with writing the language for a proposed **International Treaty of Spacecraft Design and Launch Standards** aimed at drastically curtailing the current rate of debris production.

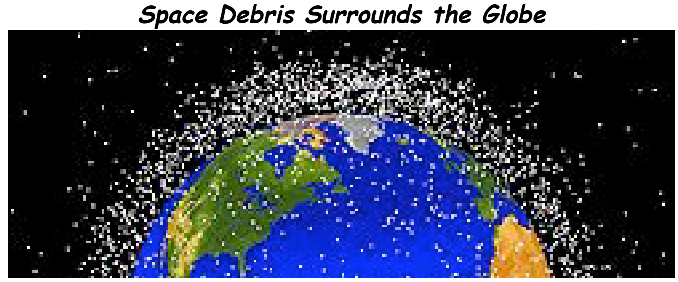
What could come out of such a study? We have some ideas but they may well be naive. We leave it to the engineers and spacecraft designers. As to the bean counters, it is hard to see how they can be part of the solution, since it is the bean counting practice of dismissing life-cycle costs that is at the heart of the problem. Could this be an opportunity for redemption?

It may take ten years for such a process to run its course, *if people begin to take it seriously now.* Sadly, it may take a killer blow for people to become concerned enough to be willing to accept design inconveniences and upfront costs necessary in the long run to keep the Space Age an open-ended Age. Even if we were to start today, there's no guarantee we could finish such a process in time.

Our attitude towards space debris is like that towards icebergs and sharks. Sure, there out there. So is lightning. So what?

Our advice is for the minority who do care to start the process quietly on their own. Rather than look for ways to cleanup what's out there, we should concentrate on slowing the generation of new debris by spacecraft yet to be launched. Once we've plugged the leaks in the damn, *then* we can turn our attention to mopping up. - **PK**

Space Debris Surrounds the Globe



Constructing an L1 Gateway on a "Just-in-Time" Schedule

(the way Business & Industry would do it)

"If the Moon had a moon, what could we do with it?"

by Peter Kokh

Asking the Right Questions

In this essay, we want to approach the idea of an L1 Gateway with a clean slate drawing board, putting out-of-sight, out-of-mind, the recent elaborate mega-proposal from NEXT, NASA's Exploration Team. Instead, we would like to answer two simple questions:

1. If the Moon had a moon, what could we do with it?
2. How could you phase in an L1 Gateway in a logical step-by-step "just-in-time" fashion while you are establishing and developing a first lunar outpost?

If the Moon had a moon ...

To be fair, we should add "a moon always parked above," for essentially, that is the great logistical asset of the L1 position. Anything parked in that gravitational "mountain pass" is always "overhead" from any outpost or vehicle on the surface on the Moon's nearside. As opposed to any satellite or craft in a low lunar orbit which would be in access range only part of the time, this parking lot in the nearside sky suggests some interesting possibilities:

- □ an ideal place for relaying messages and teleoperation instructions between one spot on the Moon's nearside and any other
- □ an ideal spot to cache supplies, equipment, tools, etc. for the use of travelers between Earth and Moon
- □ the only ideal place to put a solar power array for beaming energy to anywhere on nearside during the long nightspan period

These service opportunities could be provided one at a time, and ramped up on a "just-in-time" basis as the costs involved become justified in relation to the amount of use and savings they provide. In other words, we suspect that the L1 gateway could, and should, be grown, and phased in, just as the lunar outpost is grown, and phased in, on the surface. There is no reason under the sun to "complete" either all at once *before* operations at either can begin.

Armed with that conviction, we would urge outright rejection of the NASA-NEXT plan *even if the money were there.* It is simple common sense that the only logical way to develop something complex is in an orderly step-by-step co-evolution with whatever other developments are co-dependent upon it. But in point of fact, NASA would, if it could, develop L1 completely as a manned gateway before deciding to establish lunar surface operations (as opposed to using the gateway mainly as a Mars jump off point.)

This NASA approach may look like political cowardice, but it is a tack NASA is forced to take given the decades long lack of direction from Congress and the Administration. However this approach would only repeat the costly mistake of developing the International Space Station without reference to its logical depot functions

Both a lunar outpost and an L1 gateway facility are best left to industry and enterprise. Only they have the mindset to do either logically. "Just-in-time" development would lead to a symbiotic pair of installations. "Symbiotic growth" would accelerate, rather than delay the pace at which we could advance from deployment of the first permanent habit structure on the Moon's surface to a first permanently inhabited local resource using frontier town.

Many space activists are impatient. Some would advance the date of the first manned mission to Mars even if it chanced that any opening of the Mars frontier to settlement might be delayed decades as a result. Others would skip L1 Gateway development to make an earlier start on a first moonbase even if it meant that the evolution of that first humble outpost into a settlement were retarded. It is a basic cosmic law that impatience always backfires. So let's make the case for doing things right. *Impatience is an itch that we cannot afford to scratch!*

Upper and Lower Moonbase

It is our thesis that we should be thinking in terms of a pair of moonbases, one on the surface, one parked above the surface in space, and that:

a. we should develop both symbiotically in co-dependence
b. doing so will advance rather than retard the pace at which surface operations expand at the original settlement site
c. doing so will advance rather than retard the pace at which surface operations spread to other sites on the Moon's nearside

"Early," "Transitional," "Fully Operational" phases

Lets attempt a first trail balloon sketch of the phases by which L1 Gateway "Upper Moonbase Services" to a Surface Moonbase could be realized. This crude "reference mission plan" will be revised as others have input.

Early Phase: <u>virtual (teleoperated) staffing</u> - this is a list of services that could be provided without any on hand staff, with all control from the ground, preferably from the surface Moonbase rather than from an Earthside mission control, as the time delay would be much shorter, 0.4 seconds vs. 2,6 seconds., significantly closer to "real time."

- □ Communications Relay connecting Nearside outposts & vehicles in transit, and allowing Moonbase personnel to teleoperate robotic rovers thousands of miles away.
- □ Search and Rescue capabilities anywhere on nearside (faster, with superior resolution, than from Earth)

- Tie in with outrigger relays at L4 and L5 to reach 2/3rds of farside as well
- Fuel Depot - drone tanker ferries teleoperable from the surface would attach LOX tanks to a rack, and other lunar-produced fuels and oxidizers as they become available. This would create a "gas station" to refuel craft bound for the Moon - or for Mars.
- Solar Power Array for gateway operations (1) and for nightspan operations of the surface base and other surface installations. This array could be built and expanded in modular fashion as demand dictates. Thus the L1 gateway becomes a part of the solution of the "Nightspan Problem." The costs and versatility of such a power system will have to stand comparison with those of nuclear and non-nuclear *surface options* for providing or storing power for nightspan operations.

Transitional Phase: crews on duty when needed - If we add a habitat module complex that can accommodate visiting crews, we can do even more:

- Warehousing contingency resupply items for much more timely response to emergency needs anywhere on the nearside surface from this nearby cache accessible 24/7/365. A fresh Moonbound crew from Earth could pick up supplies even if the request came after their departure from Earth.
- A self-help Tool Crib | garage | docking port - where craft plying between Earth and Moon (and Mars) can be serviced, repaired, or assembled by the crews passing through - no permanent staff necessary
- A Mars Sample Return Quarantine Lab could be docked with the facility and staffed when samples arrive. Here isolation and quarantine from Earth's biosphere are assured and the chances of accidental contamination in either direction enormously minimized.

Fully Operational Phase: permanently staffed - As the scope of surface operations expands and the number of people on the surface grows, permanent staffing of the L1 Gateway would be in order. A permanent staff could:

- Maintain the complex and oversee its continual growth.
- Handle a steady stream of Earth-bound, Moonbound, and Mars-bound traffic, providing a more complete list of services to spacecraft, crews, passengers, and immigrants. This would eventually include hotel operations.. While passengers bound for the Moon would probably be on location only for brief visits, those en route to Mars might be there for some time awaiting a window to open, or awaiting craft assembly.
- Include a Medical Facility for first treatment of crews and passengers transferring at the gateway. This could include a Zero-G infirmary for patients from the Moon for cases where such treatment is prescribed.
- A variable G facility in which persons who have lived on the Moon for a long period can recondition themselves gradually for a visit or permanent return to Earth.
- Maintain a growing Solar Power beaming operation that supplies not only nightspan base power to permanent surface operations, but full time power to surface vehicles in transit with dedicated slaved beams with power loads on demand from the engaged vehicles controlled by feedback loops. This would greatly assist remote and mobile mining operations as well as freight and passenger transportation between surface destinations dayspan and nightspan alike.

One step at a time – Easy does it!

You can see from the above, that there is no need to plunge into the full scale development of an L1 gateway facility. Following the sequence of the Artemis Project mission plan, the first payload to be dropped off at L1 would come after the first surface crew deployed the initial permanent habitat structure and auxiliary equipment but in time for the delivery of the first rover and the arrival of the first overnighting crew.

The first L1 Gateway payload would consist of a relay satellite with station-keeping ability and a host expansion rack for the addition of add-on equipment. Would a first modular power generation and beaming array come next? This is a whole new area of logistics not previously considered by Moon mission planners. We invite all interested parties to get involved in the brainstorming. What comes when? What size and capacity when? How do we best synchronize development of this "Upper Moonbase" with the surface "Lower Moonbase?"

We will announce a discussion list address (most likely hosted on the asi.org domain) as soon as one has been set up. **<MMM>**

"Names" for an L1 Gateway

An Exercise in Idle Musing

by Peter Kokh

"L1" (Ell One) is a convenient enough designation and it could be that people will always call it by that name. But in general, it is inevitable that spacecraft and space facilities are given proper names. Here we could always follow the precedent of the International Space Station and avoid naming the complex as a whole and simply name individual modules. That may well be what happens if the L1 Gateway is built as an international multi-govenmental facility. If L1 is developed as part of a business-industry effort to open the Moon, however, bowing to international sensitivities could be less of a consideration.

A gateway facility could be named after some prominent scientist, astronaut, or politician, or bureaucrat.

That certainly leaves us with a large pool of names of persons associated with the Moon: Armstrong, Lovell, Borman, Von Braun, Schumacher, and on and on. It would be a pointless exercise to pick a favorite here.

Or, as has often been done before, we could turn to the pool of names from ancient mythologies. Let's see where that takes us. We find:

- **Hecate** would be good for L3 on the opposite side of the Moon's orbit, with Earth in between and "hiding" the Moon. Ancients called the Moon "Hecate" when it was below the horizon, before rising or after setting.
- **Endymion** (m) was the mortal beloved by Selene (f) (Greek Luna) (but not an actual lover.) He was placed in eternal sleep to be the eternal lover of Selene
- **Pan** (m) was a god to whom Selene submitted -- "pan" is also Greek for "all" (= Roman "omni"). Pangate would be doubly fitting i.e. serving all destinations (Moon, Mars, asteroids, etc.) as this is the function that currently endears it to the NASA Exploration Team.

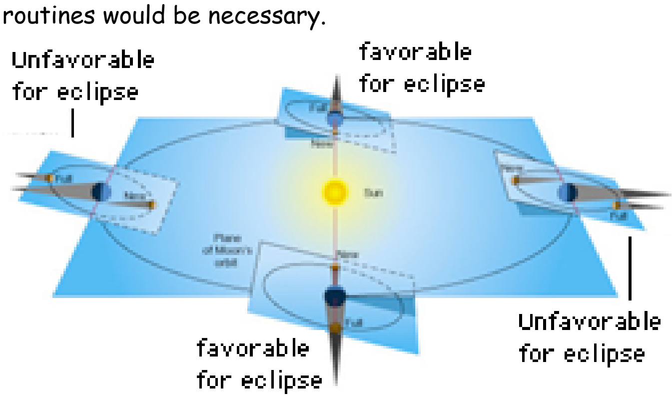
So **Pan**, or better yet, **Pangate**, is our pick for best mythologically appropriate name choice to compete against the most popular choice from the list of mortals associated with the Moon, four of them mentioned above.

Of course, if NASA names it, it will be imaginatiely known as "The L1 Space Station".

L1 in Eclipse

If the Moon's orbit around the Earth lay in the same plane as Earth's orbit around the Sun, there would be a total lunar eclipse every month at the time of full moon. But as the Moon's orbit is significantly inclined, there are only two or three times a year that the Moon passes through the Earth's shadow cone. L1 would share that orbit inclination and eclipse frequency.

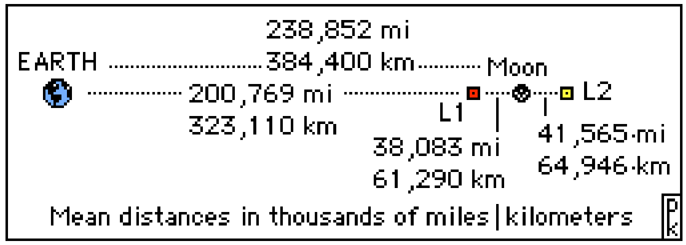
At such times, the station could be without solar power for as much as four hours. Thus backup power generation, power storage, and/or sleep mode operations routines would be necessary.



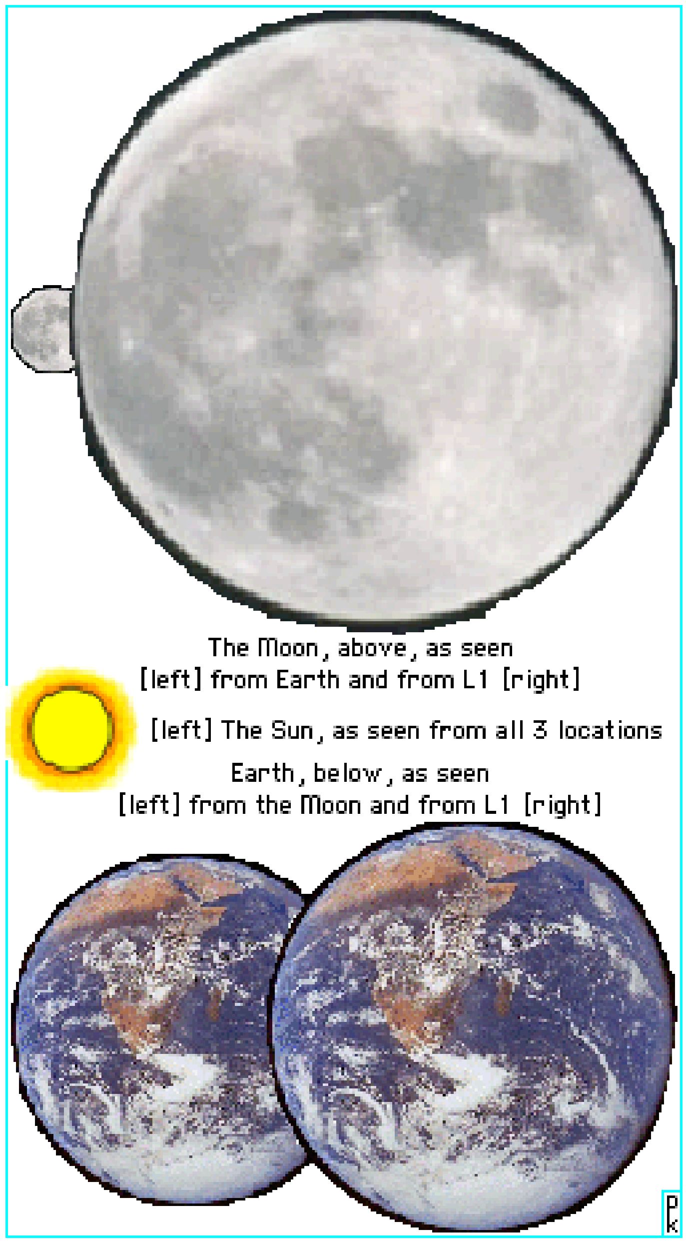
The View From L1 Gateway

by Peter Kokh

L1 is 84 % of the way from Earth to the Moon:



0°31′ apparent size of the Moon from Earth
3°14′ apparent size of the Moon from L1 Gateway
1°54′ apparent size of Earth from the Moon
2°15′ apparent size of Earth from L1 Gateway



Clearly, anyone stationed at (or passing through) the L1 Gateway, will "have the best of both worlds!" <MMM>

Making Glass on the Moon

by Dave Dietzler <Dietz37@msn.com>

The Trend in Building Materials on Earth

In a future time when clean electricity from solar power satellites and helium 3 fusion powers the world's machines including home furnaces and automobiles, it will be possible to make structural plastics from remaining petroleum reserves and abundant coal. Burning oil is such a waste. There will be plastic two by fours, sheets, planks and trim that are as easy to drive a nail through as wood. We already have vinyl siding. Houses will also be made of steel frames and brick with fiberglass insulation. Plastic won't rot or suffer from the effects of water damage and houses made from it will last for centuries. We will no longer have to chop the world's forests down for lumber. Plastic will make it possible to save the Earth.

Lunar pioneers must rely on other options

On the Moon, we won't have the luxury of cheap plastic, paper or wood, perhaps not even after polar ice deposits that include some nitrogen oxide and carbon oxide ices are tapped. These materials, so cheap on Earth will be the precious ingredients that sustain our mini biospheres and pretty much reserved for life cycle uses. Iron and other metal alloys, cast basalt, ceramics, concrete, and glass will be our chief manufacturing materials on Luna.

When it comes to glass, fused raw regolith will make an inexpensive, plentiful, but dark product, suitable for tableware and vases and giftware. By varying the mix of mare regolith and highland regolith, for example, a beautiful glass of variegated gray and black shades should be easy to make and popular. "Settlement Glass," it will likely be called. I can just see the dark bottles of Oceanus Procellarum Beer, brewed on the Moon. But to get beyond this stage we will have to choose the ingredients for our glassmaking recipes with care.

Soda-lime glass is typically 70-74% SiO_2, 1-2.5% Al_2O_3, 12-16% Na_2O and 8-14% CaO by weight. Sometimes a little MgO is included. Oxygen, silicon, aluminum, calcium and magnesium are plentiful on the Moon, but sodium is a little less common. Sodium is present in regolith at about 3.3 parts per thousand. From a million tons of regolith, or a square pit about a quarter of a mile on a side ten feet deep, we could get 3300 tons of sodium for 4450 tons of Na_2O. If our soda-lime glass is 14% Na_2O, we could make almost 32,000 tons of conventional glass. That would be plenty (to a ridiculous extent?) for "indoor" or "middoor" windows, bottles, tableware and more for a colony of several thousand people.

All soda-lime glass items will be recycled. Returnable soda bottles with a ten cent deposit will be resurrected on the Moon. Billions of tons of maria regolith will be processed by mobile mining vehicles to get helium 3, but this only involves roasting out the volatiles. Processing regolith for oxygen, silicon and metals will be more complex and use more time and energy, so we will only go through a few million tons of dirt for Oxygen, Silicon and metals a year. Recycling of glass to conserve less abundant elements like sodium will be essential.

There is very little boron for making Pyrex glass on the Moon. If regolith is treated with hot fluorine gas to extract silicon, some boron trifluoride gas that can be separated through fractional liquefaction will also result. From a million tons of regolith we could get a couple of tons of boron. That isn't much. We might want to import some boron. We could also use pure fused silica glass for laboratory ware, outer windows exposed to high temperatures and thermal shock and cookware. Although fused silica consisting of 100% SiO_2 is hard to make and work with because of its high melt point (1700-1800 C.) it will be worth it for these special purposes.

Glass for a myriad of consumer needs

What about supplying the demand for glass by millions of Lunans and Space Oases dwellers? What if we want lots of glass fibers, glass pipes, glass walls, glass doors, woven glass fiber fabrics, and many other glass items for a growing population in space? We aren't going to make it all out of fused silica and we don't have that much sodium.

The answer is aluminosilicate glass as described by Geoffrey Landis in his article "Glassmaking on the Moon" [Artemis Data Book (http://www.asi.org/adb/fulloutline.html) http://www.asi.org/adb/02/13/01/glass-production.html] A boron-free formulation of aluminosilicate glass would be approximately 60% SiO_2, 20% Al_2O_3, 12% MgO, 5% CaO, 1% Na_2O, 1% traces.

With this formulation, over 400,000 tons of glass could be made with the sodium in a million tons of regolith. There's enough silica to make this much glass in a million tons of regolith, but some extra alumina and magnesia will be needed. Aluminosilicate glass will soften at a higher temperature than soda-lime glass, but it will be much more workable than fused silica.

Optically Clear Glass

Transparent glass must be iron free. Fortunately, we will use electromagnets to remove iron from regolith and produce iron free feedstock for glassmaking. In some cases, we will actually want to add iron to our glass. Amber colored glass can be made by adding iron sulfide. Blue-green glass can be made by adding iron chromite. Yellow-green glass can be made by adding chromic oxide and blue glass can be made with cobalt oxide. Red glass can be made with cadmium sulfide or cadmium selenide. A few hundred kilos of selenium and a few kilos of cadmium exist in a million tons of regolith. Although we should be able to get that cadmium and selenium when distilling regolith for zinc, there won't be much glass tinted red on the Moon. [The only inorganic true reds are compounds of mercury or lead and both elements are very scarce on the Moon. - Ed.]

Cobalt Blue Glass (from www.glass.co.nz/encyclopedia/

Small amounts of cobalt (c. 1 oz/ton of glass) are used to neutralize the yellow tint of iron in glass such as window glass. To produce a blue color in glass, you only need to add five ounces to a ton of glass. Deeper blues are obtained by adding up to ten pounds of cobalt oxide to a ton of glass. This deep blue glass can then be ground up into a powder called "SMALT" which is used as a coloring agent for enamel, for glazes on pottery, and for making more blue glass.

So, if we get 25 tons of cobalt from the magic million tons of regolith, we could color over 5000 tons of glass deep blue and 175,000 tons light blue. That's a lot of paperweights and dinner ware.

Glass Brings Color to a Gray World

A combination of colored glass (though it may be mostly amber or blue-green), sodium silicate based paints, flowers, green plants, aquariums with bright tropical fish or gold fish, terrariums and bird cages will make our mostly gray metal, concrete and black stone subsurface dwellings more pleasing to the eye. Combine this with some live and piped in music, fountains, waterfalls and imported or Moon-grown potpourri and we will have some real nice places to call home on the Moon. Light will come from heliostats with UV filters by day and sulfur lamps by night that closely mimic natural sunlight to bring out the colors.

Market Sink for Recycled Glass

With all this aluminosilicate glass available we will be able to extrude fibers from trashed glass and add it to cement for a stronger concrete as described by Peter Kokh in the Sept.,'02 MMM #158. I can see the older generation from the days of tight glass recycling being appalled by the younger set getting drunk and smashing disposable bottles and wine glasses. "So what, pop? It's all going in the concrete! Come on, it's not like we're tossing plastic or paper in the trash!" Aluminum beer and soda cans will end up in the concrete too, so young Lunans and old will have the joy of just throwing stuff away without guilt. Call it consumer culture.! [See our remarks below. - Ed.]

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Recycling Glass & Other Materials in Lunar Settlements

by Peter Kokh

Many thanks to Dave Dietzler of the Moon Society St. Louis Outpost for another great article.

Dave is correct to point out that as mentioned in my previous article on Concrete, which he cites, glass shards can be used as decorative aggregate in concrete. He is also correct in saying that aluminum and other post consumer "trash" can end up in that sink.

That said, we beg to differ on a wisdom of general tolerance for such kinds of disposal. There is more to consider than that. Those materials that incorporate a lot of energy in their production should preferably be recycled in a way that captures as much as possible of that energy.

The best way to recycle glass is in the production of more glass. The best way to recycle aluminum is in the production of more aluminum. There are plenty of rocks and aggregate rubble on the Moon to serve as filler for concrete at little energy expense. If we toss aluminum scrap into the concrete batch, that means more electricity must be generated to replace that aluminum than would be the case if we simply recycled it properly.

Glass recycling, as most of us who try to do it know, can be tricky. You have to keep the colors separate, and some kinds of glass can not yet be economically recycled at all - the mongrel glass in the so-called "disposable bottles."

There may be incentives for business to find uses for various orphan categories of post consumer waste. And there may well be an effort to design consumer products for designated afterlife usages. In the 70s there was an attempt to design a "world bottle" with a shape that would let it serve adequately as a building brick when empty. It would be a good idea to take another look at this challenge. Today, an increasing number of businesses are seeing the economic sense of reuse design.

I think that young Lunans will grow up learning the Four "R"s - "Reading, wRiting, 'Rithmatic, and Recycling." On the Moon we will always be behind the proverbial Eight Ball in fighting the odds in a never ending struggle to survive in a decent and satisfying fashion. The better we attend to our Ps and Qs, the better our chances of a good life. The more sloppy and careless we allow ourselves to become, the more quickly the curtain will fall on an a self-aborted effort to settle a new world.

Young people can be given the yeoman chores of recycling, and do their universal service in all the utility systems upon which survival on this unforgiving world is possible. That should instill in most of them a second nature habit of care and concern. Plainly put, it will take a bit more to make a good Lunan citizen than what sadly passes for a good American citizen. **<PK>**

Will Settlement Change The Moon's Appearance?

by Arthur P. Smith and Peter Kokh

Thoughts on a Controversy & Artists to the Rescue

Arthur P. Smith <apsmith@aps.org> 10-27-02

A couple of thoughts I had:

(1) we've had this slight bit of controversy the last six months or so [in the Moon Society discussion lists] about "development" of the Moon, and how that could spoil it for all the Moon lovers down here on Earth. I think some images showing the potential for transformations of the face of the Moon in future might gain us a lot of good will. The Heinlein cover with split Earth/Moon that Ian [Ian Randal Strock, Editor] ran on **Artemis** magazine recently is an example of the idea - would the Moon not be more beautiful if it was endowed with the colors of life, rather than its current grayscale desolation?

You could start from a full-Moon image as it is now, focus in on, say, Mare Anguis and a Lavatube development, making at first almost no perceptible change in lunar appearance. What change in fact would it make? The shimmer of solar panels? Radiators hidden from the sun? A variety of mining vehicles, and a landing/launch facility on the surface... Would any trace of the inner life seep through a "skylight"?

Then fast-forward a few decades - the shimmer and skylight effects spread, new structures rise above the surface; a "mass driver" or two are installed for transport of lunar materials elsewhere; lunar solar power stations covered with solar panels and dotted with radio telescope-like transmission antennas appear. But all of these would be close to invisible from Earth - what would such changes in relatively tiny patches of the Moon (less than 1% of area, more on the edges than in the center) look like from that enormous distance?

Development then spreads further - craters are enclosed, some locations become highly desirable, others less so. Clusters of blue-green-brown appear amid the gray. What would our moon look like, with tiny flecks of color, concentrated here, sparser there?

(2) Sublunar life. At first a lot of what is done will be underground, for radiation protection and thermal stability. How will agriculture and industry mix beneath the surface? Lighting and temperature in an ambient -20 C environment. Lots of mushrooms growing in the dark? Chickens, rabbits, pigs on a farm? Giant sulfur lamps lighting acres of growing wheat and corn? Algae growth pools and drying facilities. Workshops where bulk lunar metal is forged, and united with electronics and light machinery imported from Earth. Sports arenas. Homes that are some cross between a cave and a modern cottage. And some airlocks, barriers, and other safety devices to guard against loss of atmosphere.

There's lots of things an artist could work on, fleshing out the vision we have of lunar development. I'd love to see it happen!

Changing the Moon's Appearance: & Reality Checks

Peter Kokh <kokhmmm@aol.com>

Near term, I doubt that we could do much that was noticeable. If we did widespread harvesting for surface volatiles, that "gardening" operation would tend to raise the albedo a bit for the areas covered, making them brighter.

Surface Night lights from the settlements might be noticeable in telescopes, but a settlement would have to be pretty humongous for its surface lights to be noticeable from Earth. Most of the activities that are supported by outdoor lighting on Earth would take place indoors or middoors on the Moon. Surface roads would be fewer in number than the subsurface ones at least in urban areas.

That said, I'm all in favor of a lighthouse beacon on the Moon at the intended settlement site before the first Moonbase module is landed. Green light is supposedly the most visible, and also the least disconcerting. Green signifies "life," "okay," "go."

Most changes would be so gradual, that no one would really notice. In stark contrast, the changes we have wrought on Planet Earth as visible from the Moon over the past century must be startling! The bright light clusters from urban areas and gas field burnoffs are something new in the past century for prospective observers on the Moon. but I think most would see that a beauty, not pollution.

There are concerns, but I think less about mining activities and other physical alterations that might change the appearance of the Moon to lovers on Earth. I worry about something else, something more difficult to fight, something much more insidious.

If our habitats were leaky and there were enough of them, there might be some slow faint rusty gray patches around settlement areas as some of the free iron fines were oxidized by traces of humid air. As more and more volatiles are pumped into the vacuum from rocket exhaust and leaky airlocks and seals, the longer it will take to dissipate into space. In time the extremely tenuous lunar atmosphere would be come progressively less tenuous. There would be more and more rusting, and someday, even occasional dust clouds.

We have written about dock-locks, snuglocks, barometric airlocks, turtle back suits, iron fine burning rockets, and other contraptions that might help conserve air, slow leakage losses, and slow vacuum degradation. The lunar vacuum is a priceless scientific-industrial resource. We shrug our shoulders at its slow contamination to our ultimate irrevocable loss. **<PK>**

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