

Moon Miners' Manifesto

& Moon Society Journal



MMM Classics

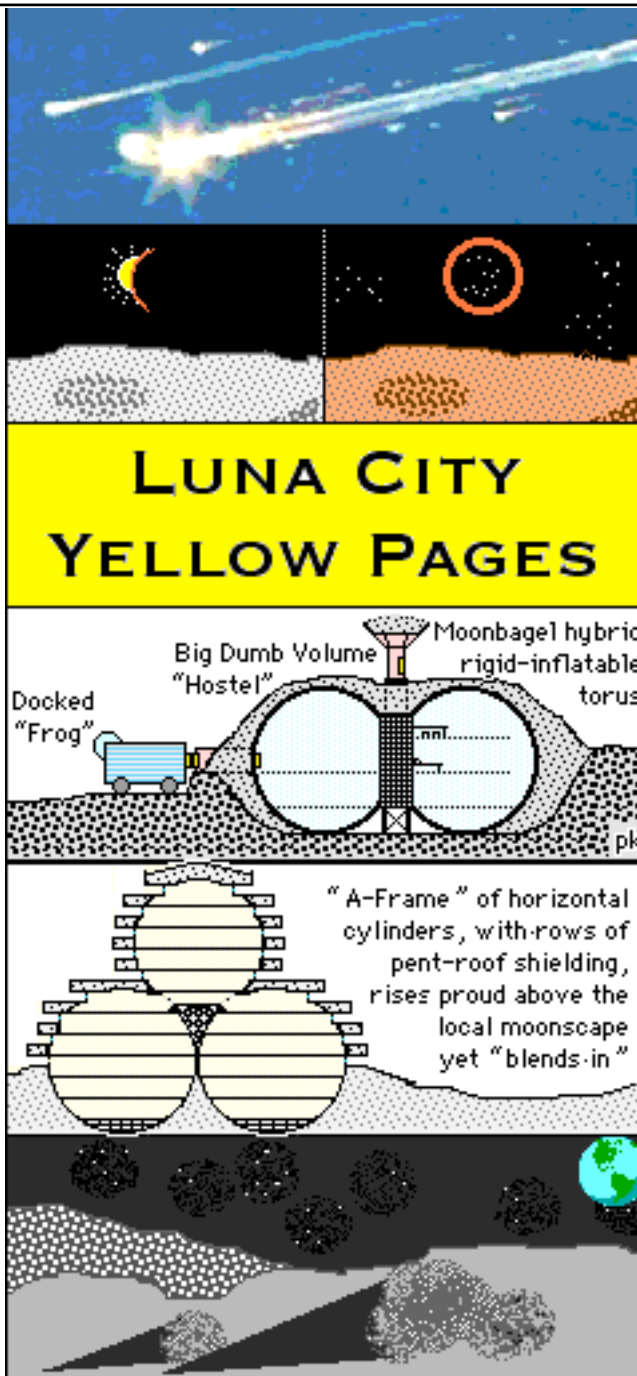
Year 17: MMM #s161-170
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Once again, we switched fonts to **Gadget** for headings and Comic Sans for text. In the first issue we talked about casein-based lunar paints and about how lunar Tourist facility clusters would develop & grow.

But this year was far more memorable for the tragic loss of the **S.S. Columbia crew** on their return from orbit. In this same issue, #162, quite fittingly, we wrote about the men and women who would be most likely to go to the Moon as pioneers of a new homeworld.

Our annual Mars-theme issue took up several issues: its unique colored skies & daylight, the need for more wearer friendly "skinsuits", and using solar sail cargo shipments to get around the 2 year long wait between launch windows.

In issue #164, we wrote about how special it would be to experience a total lunar eclipse from the Moon itself. Dave Dietzler wrote about "cycling" Earth-Moon ferries that would make travel "posh.". We also added a special one page feature to this and following issues, **LUNA CITY YELLOW PAGES** to illustrate how every bit of progress on taming the lunar frontier would give birth to new rounds of enterprise creation and build the domestic economy.



In MMM #165, we speculated that home garden tours would become a favorite weekend pastime for settlers. Craig Beasley took a look at the Lunar Reclamation Society's paper on "Lunar Hostels" and developed the concept further as a means to transit quickly from a first landed module to a complex that would have full functionality when docked with a visiting crew vehicle.

The following issue featured an article about the ancient game family of pits and pebbles known variously as Mancala or Oware, as an game easy to manufacture on the frontier and one of captivating strategies. We also took up the issue on whether buildings on the Moon should "stand proud" or "blend in." - both!

Several articles this year took up a favorite topic: recreational & other activities out on the radiation swept surface. Construction of self-paved roads for light traffic should be relatively easy. In time, some pioneers might adopt a nomadic life style, trucking goods and supplies providing services, etc. They will need specially shielded vehicles and roadside facilities. *Enjoy!*

In FOCUS: Vision must be defined in terms of Obstacles & Challenges

Every movement and organization and enterprise has a basic, success-enabling need to define itself in terms of its Vision and Mission. For us in the pro-Space community, a Vision Statement describes the kind of world or universe in which we want to live, but is not yet at hand. The Mission Statement lists the means at our disposal by which we propose to work and strive to realize that Vision.

The Vision Statement

In composing our Vision Statement we list things which are not yet reality: "communities of people living and working beyond Earth's surface," for example; or human settlements in space, on the Moon, Mars, and elsewhere, using the resources of those places both to support themselves and help solve difficult problems on Earth." In the latter statement, we have included references to real challenges: sustaining life on worlds and in locations far less blessed with resources than our homeworld; helping overcome problems on Earth such as a growing need for abundant, and clean energy.

Stating a Vision Statement in reference to the challenges and obstacles in the way of its realization is definitely useful, perhaps even essential. Simple common sense should tell us that any Vision that does not explicitly recognize the obstacles and challenges in that stand in the way of its realization is no more than a grandiose group hallucination.

Why is statement of the principle obstacles and challenges that important? It's simple. The statement of obstacles and challenges define the Mission of the organization or enterprise, setting the principal Agenda for the effort. Is this not tantamount to combining the Vision and Mission Statements into one? No, because the Mission Statement must do more; it must list the principle means at our disposal by which we can make progress in addressing those obstacles and challenges.

The Vision Statement then is much more than a Prophecy. And membership much more than a matter of getting a front row seat from which to watch the grand vision unfold. For the Vision is clearly not guaranteed. There are obstacles and challenges that need to be addressed and overcome by marshaling all the resources available to the organization or enterprise, and if these are insufficient, then by aggressively developing the missing tools and resources. The Vision is a Dream to be realized by Work. The Mission outlines a work strategy.

How are space Society's doing?

I'm not sure an MMM report card can be accurate or helpful, and may even be counterproductive by stirring up defensive reactions. But let's take the plunge. Rather than take offense at low scores, we hope society leaders will be inspired to more effective and comprehensive overall efforts. .

Planetary Society

- Excellent development and follow through on projects that advance the realization of its Vision.
- Aggressive pursuit of resources needed for projects.
- Poor marshaling of the talents of individual members
- Does not encourage or recognize local chapters.
- Overall Score **A-**

National Space Society

- Addresses legislative and political obstacles only, not seeing any other obstacles as within its purview because it considers members as mere check writers and political activists, ignoring a tremendous talent pool of tens of thousands of gifted persons.
- Will not consider projects that can't be funded out of membership dues left over from basic operations.
- Self-limiting effectiveness. Overall Score **C**

Mars Society

- Has a definite Vision and Mission Statement that identify concrete areas of activity that will advance the realization of the Mission.
- Aggressive Projects Policy, going out and finding needed resources it does not already have.
- Initially aggressively sought to put the talents of all its members to work, but now neglects this resource.
- Some Task Forces are floundering. without leadership.
- Some real successes. Overall Score **B++ / A-**

Artemis Society

- Has a definite project but doesn't engage in periodic review and self-reinvention. Website projects only. Concentrates on fine-tuning the "reference Mission," ignoring challenges it could benefit from addressing.
- Self-selected ineffectiveness. Overall Score **B**

Moon Society

- Except for one reference to the need to get private enterprise involved in developing technologies needed, Vision and Mission Statements seem to be those of a fan club: "we're interested in all things Moon and we are the place to talk about it." No game plan or strategy to leverage what resources it does have.
- No strategy to marshal the talents of its membership, much less identify them, except for involving them in discussion groups and web projects
- Waiting for more members before taking on projects
- A dedicated core without a plan. Overall Score: **C**

MMM wants all these Societies to succeed!

We point out shortcomings as would a friend. **PK**

Cheesy Paints for Lunan Artists

by Dave Dietzler <pioneer137@yahoo.com> and Peter Kokh

Casein Based Paints by Dave Dietzler

A painting medium in common use by artists here on Earth, "Casein-Tempera Emulsion" may lend itself to use by early lunar pioneers. Casein [Latin case(us) = cheese] is a protein precipitated from milk and is the basis of cheese and some plastics. An emulsion can be made of this protein, water, and lime to serve as a binder for fine art paints. Tempera is a painting technique using such an emulsion. Casein sets quickly, mat, and transparent, all of the pigment is exposed, making a very luminous surface..

Early settlers may not enjoy fresh milk from goats, much less from dairy cows, but powdered milk may be a regular imported food supplement, and source of casein.

You can read more on this medium and how to prepare and use casein tempera emulsions, at:

<http://www.mauigateway.com/~donjusko/final.htm#CASEIN-TEMPERA>

"Lunar Kosher" Considerations by Peter Kokh

While this tempera emulsion may work with many inorganic pigments, casein, being organic, in our opinion should be reserved for use with organic dye stuffs so that waste paint and discarded artifacts can be recycled into the biosphere. Yet most vegetable dyes apparently "bleach out" when used with casein emulsions.

This creates quite a challenge for would-be Lunar Appropriate Art Media Pioneers {LAAMP} It would be great to have another paint medium than inorganic sodium silicate (waterglass) in order to diversify the art media options open to Lunar Pioneers. But how do we do achieve this goal? Experimentation is essential. Any satisfying results may lead to a Casein-Tempera medium quite distinct from that practiced here on Earth.

This may seem an absurd concern for those pre-occupied with frontier hardware questions, and even those concerned with lunar agriculture and biospherics. But in the long haul, the burden of transforming a bleak frontier into a truly human one will fall on the shoulders of pioneer artists and craftsmen who find ways to transform moon-dust-based stuffs into human expressions of beauty. Art and craft are not luxuries. The battle for the Moon will be won or lost on a host of fronts: metallurgy and other materials science, engineering and architecture, agriculture and biospherics - we understand those. But it will be a battle not just to establish and preserve environments that sustain the body, but also a battle to establish environments in which the human spirit can thrive and reach new heights.

read about our previous attempts at a lunar-appropriate painting medium at:

<http://www.lunar-reclamation.org/page15.htm>

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Tourist Clusters on the Moon

by Peter Kokh

Foreword

In MMM #136, JUNE 2000, pages 5-8, we wrote about an "All-in-one Moon Resort." This article described the general advantages of various locations on the Moon from the viewpoint of visibility of Earth above the horizon, concluding that locations on the limb, where due to libration effects, Earth was sometimes just above and sometimes just below the horizon offered the "best of both worlds," that is, the advantages of Nearside locations along with the advantages of a Farside one.

The article also traced a surprising scenario, which is becoming more and more plausible as time goes on: tourism, not industrial development of lunar resources, may pace the opening of the Moon. We have put this article online at the following address:

www.lunar-reclamation.org/moonresorts_paper.htm

What follows is a fresh, shorter, look at how tourist facilities are likely to multiply on the Moon.

The Dawn of Lunar Tourism

We are, alas, still a long way from returning human pioneers to the surface of the Moon. There are no NASA plans to do so - all such previous studies gathering dust on the shelves per instructions from Congress - and amorphous plans of China, India, and Japan to put people on the Moon cannot yet be taken seriously, none of these nations having yet put an astronaut in orbit. The Artemis Project would set up a first commercial Moonbase, and indeed, this seems a more plausible eventuality than Congress reversing course and ordering NASA to shake a leg.

Everyone waits for someone else to put precursor pieces of the terracing puzzle in place, however, and so we do not seem to be making any real progress. That none of the would be movers and shakers has a critical amount of seed money is the harsh reality, of course.

We have all been quick to herald the opening of the Space Tourist age with the ISS visits of Dennis Tito and Mark Shuttleworth, the first "kids on the block" to come up with icebreaking money. Efforts to get additional camera-toting commoners into space through "creative financing" have so far not succeeded. That's to be expected. The more we rely on multiparty financing, the more failure points we introduce into the plan.

Yet interest of "ordinary people" in space tourism remains quite high. Once someone succeeds in bringing down the ticket price by a factor of ten, then a hundred, the floodgates will first crack, then shatter. Regular traffic will lead to dedicated, if spartan, orbital tourist quarters. As prices continue to come down, and the number of ticket purchasers grows, whole new orbital tourist centers will be developed, unconnected to ISS.

Once we have a dedicated tourist shuttle, it simply requires refueling and reprovisioning that craft to send it and its passengers on a no-land loop-the-Moon up-front-and-personal venture following the default path taken by the limping Apollo 13 craft. Indeed, as we have pointed out previously, tourists could skim over the Moon's farside *before the next humans return to the Moon's surface*. It is a simple fact that landing on the Moon, and then returning, requires additional hardware and fuel. You can read more about "Lunar Overflight Tours" online at:

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

But where do we go from here? In the MMM #136 article cited above, we suggested that a dedicated surface "hotel" complex might be developed in Mare Marginis (or some other "limb" location.) But the actual step by step development of lunar surface tourism may start quite humbly, without any surface facilities at all. The first tourist lander craft will serve as a self-contained hotel, exactly as the Apollo Lunar Excursion Modules not only brought astronauts to the surface, and then returned them safely to lunar orbit rendezvous, but served as their "camp" while on the surface. Such a craft could set down just about anywhere on the Moon's surface, perhaps visiting a different location on each trip. This "butterfly" strategy would encourage repeat visits by some of the well-heeled early Moon tourists. And as anyone in business knows, the repeat customer is a principal mainstay of success.

First Dedicated Tourist Surface Facilities

From this point in time, it seems obvious that the first permanent habitat on the Moon will be a module (with auxiliary equipment) manufactured on Earth and transported to the Moon's surface. There is simply no other way to get started. We cannot rule out the possibility that once the facility is field-tested, debugged, run through a full lunar dayspan-nightspace cycle and judged "operational" by advance crews, its intended design use will be *for tourists*. After all, we do need to make the first outpost earn money, and tourism is certainly a promising source for a steady revenue stream.

However, this approach would seem to be a dead-end one. Bringing pre-manufactured ready-to-deploy-and-use habitat space from Earth is forbiddingly expensive. There will be no way to get beyond the "rugged campsite stage" without first developing the capacity to produce lunar building materials, *and modules*, from processed local moon dust - regolith. So while hosting occasional tourist visitors will be an important way to raise capital for testbed lunar industrial experiments, the principal and regular occupants of a first outpost will need to be those pioneering the early industrialization route. Only when we are ready to begin manufacturing, and assembling, and outfitting expansion habitat and function space from modules manufactured on site, can surface tourism grow.

Scattered Tourist Sites vs. Tourist Clusters

Here on Earth, there is a seemingly inexhaustible number and variety of tourist destinations, facilities, and activities from which to choose. In fact, this has been the case since at least the middle ages, but has never been so manifold and so accessible to the general traveling public as today. Yet while we can fly here today, there tomorrow, on a butterfly itinerary that samples many locations, a mainstay of surface tourism, especially for the driving public, has been the tourist cluster: one general destination that offers a great variety of facilities and activities.

The tourist cluster comes in many sizes. There are the mega-clusters of Orlando and Las Vegas, of course. But we are thinking of the many smaller clusters around the country whose development preceded these modern day wonders. Inspired by my own experience, four "gateway" clusters come to mind.

- Wisconsin Dells, WI - gateway to the scenic Dells of the Wisconsin River
- Estes Park, CO - gateway to Rocky Mountain National Park
- Gatlinburg, TN - gateway to the Smoky Mountains National Park
- Cave City, KY - gateway to Mammoth Cave National Park
- *And there are many more similar clusters*

First Outpost / First Tourist Surface Itinerary Synergy

Now on the Moon, we will, in time, have clusters of tourist facilities and for-profit attractions (frequently disparaged as "tourist traps") at gateways to some of the Moon's more outstanding scenic attractions: the crater Copernicus, approaches to the Alpine Valley, for examples. But it seems certain that the very first lunar tourist cluster will grow up in close proximity to the first lunar commercial-industrial outpost as it gradually develops into a true settlement.

Tourism requires support facilities and support services and people "on location" to man them. However, it will be a while before the tourist stream becomes a steady one and requires the "day job" attention of support cadre on location. In the beginning, tourists will arrive in small groups at infrequent intervals. Tour group leaders familiar with the outpost and the lay of the surroundings can themselves provide much of the support.

They will have the Outpost to visit, and make the tour of surrounding support facilities: solar arrays, fuel tank farms, construction sites, road-building sites, regolith harvesting and mining sites, processing facilities. And, of course, the local scenic highpoints.

As the stream of visitors grows in both numbers and frequency, one can imagine a definite symbiosis emerging between the tour operators and the Outpost and its staff. For example, an additional pressurized motor coach/crew transport could be paid for on a time-share

basis by both the Tour Operator and the Outpost Agency and bring real benefits to both. New roads serving new scenic attractions as well as new mining or processing sites could be built. Tour Operator need for automated self-help rest stops would seem to be a made-in-heaven match for the Outpost's needs for a network of service garages/emergency flare shelters. In short, we can expect a real, if partial, synergy between the driving needs of Tour Operators and the driving needs of an Outpost aggressively expanding in both size, staff, and diversity of activities.

That there will be some friction and disagreements will not discourage such a partnership. Only an Outpost that aggressively seeks to expand along for-profit vectors has any real chance of morphing into a real settlement. And we all know from experience here on Earth how important an economic driver tourism can become.

Location, Location, Location

It could happen that the first outpost-settlement-to-be will be quite close to a major scenic attraction. But it is more likely that scenic advantages will be an important but secondary consideration in site selection. Yes, to support a variety of marketable services, we will want a photogenic site, one with interesting moonscapes, and one from which Earth hangs in the sky not uncomfortably far above the horizon (in "The Postcardlands".) It is also likely that the outpost planners and site-pickers will have the foresight to realize that a mare-highland "coastal" site will offer the best strategic advantages for industrialization: access to both mare and highland suites of lunar regolith resources. And such a site will be much more interesting from a tourist point of view: vistas of great plains along with a setting of nearby mare basin rampart mountains.

Two such site proposals are Greg Bennett's "Angus Bay" (commonly known as Mare Anguis, Sea of Serpents, an irregular winding mare-filled bay off the NE "coast" of Mare Crisium) and our own "North Junction" proposal for an outpost along the north coast of Mare Frigoris at the overland gateway to the north polar icefields. Both offer comfortable Earth viewing and a mix of plains, mountain ramparts and craters.

In time, as diversification of the economy leads to the spread of human presence to many distant locations on the Moon, more scenic attractions will become accessible. A first "service station / flare shed / inn could lead to a cluster of tourist facilities of which providing access to the flagship scenic attraction in the area will be only the first. In clusters, whether of tourist facilities, fast food restaurants, or automobile dealers, everybody benefits from increased traffic. The cluster provides something for everybody within a relatively small area, so more time can be spent on enjoyable activities, less on traveling from one to the other. Industrial diversification keyed to special ore concentrations may lead, but tourism will help build the future map of the humanized Moon. <MMM>

Killer Debris vs. Killer Asteroids

by Larry J. Friesen <ljfriesen@ev1.net >

On the "In Focus" Editorial Essay in MMM # 160, "Killer Asteroids versus Killer Space Debris", you seem to belittle the danger from rogue asteroids (and comets). I know something about both topics, both serious concerns. Compare them is like comparing apples and oranges; they are very different types of dangers, involving hugely different time scales.

The Threat of Asteroid Impacts: To put the danger from impacting asteroids and comets in perspective, the chances that any person will die in a meteoric impact are about the same order as the chances that they die in an airplane crash, based on the past rate of impacts on Earth, as well as we can reconstruct and estimate it. A major difference is that most deaths from meteoric impacts will be due to extremely rare bolides large enough to devastate a large region, a continent, or perhaps the entire planet. It may be tens or hundreds of thousands of years between "state busters", and perhaps millions or tens of millions of years between "continent busters" or "planet busters". But when they do occur they will kill huge numbers of people; perhaps millions or even billions at a time.

Many people - including the news media - have a difficult time dealing seriously, both on an intellectual level and an emotional level, with events that are extremely rare, but have enormous effects when they do happen. It seems difficult on the one hand to avoid the "giggle factor" and take the matter seriously at all, and on the other hand to avoid over blowing it. How we get the average person to get over that mental "hump" I don't know.

We've apparently got the media past the "giggle factor". But we may not yet have gotten them to get enough perspective on it to keep from over blowing things. It may be difficult to get them to take a calmer perspective, because news media seem to thrive on sensation.

The Threat from Orbital Debris: Turning to the very serious problem of orbital debris, I've worked in that area. as a part of the NASA - Johnson Space Center (JSC) orbital debris study group. It may interest you to learn that there have been a series of international workshops on the topic, such as you propose. I've participated in a few. NASA's orbital debris experts, along with interested parties from DOD and other agencies, would meet with our counterparts from ESA, Russia (then still the U.S.S.R.), Japan, etc. We would exchange information about what we'd learned about various aspects of space debris, discuss policy recommendations for our various space agencies, and so forth.

Although I'm not currently working in this area, I have no reason to think that these international workshops are not still being held, on a fairly regular basis.

I'm not so sure about a treaty governing practices for reducing the creation of space debris,. I had some

Meandering through the Universe

Column on the Cooperative Movement on the Space Frontier

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Space Frontier Dawn Period

interesting discussions about this with Joseph P. Loftus, now retired, who was then one of the associate or assistant directors for JSC. He was a participant in the orbital debris study group, and led many of the discussions, especially those behind the scenes, to push various national space agencies, and international regulatory bodies (UN bodies and others) to adopt sensible policies that would minimize the generation of debris from space operations.

What he, and the rest of us, didn't want to do was to freeze a set of mandatory policies in place by treaty. First, we were getting very good cooperation from nearly every nation with space launch capabilities by presenting recommended policies in the frame of "these are practices that wise spacefaring nations should follow", with a sort of "Good Housekeeping Seal of Approval". It is not too difficult to explain matters to the leading scientists and engineers of nations that have, or are developing, space launch capability, and to get them to realize that when it comes to orbital debris, it is literally true that "what goes around comes around": any junk a nation puts into orbit is as much a danger to its own satellites as it is to every other's.

Second, we were still studying the orbital debris situation, and while we felt we had some useful policy recommendations to make, we weren't sure we completely understood everything yet. In particular, we weren't absolutely sure we knew what the best policies would ultimately be. Joe Loftus pointed out something you may already suspect: that if we fixed a set of rules in place with a treaty, it would thereafter be infernally difficult to change them, even if further research showed that there were better ways to deal with the problem, or even showed that some of the original rules did more harm than good.

Having been away from the orbital debris world for awhile, I am not certain how mature the present researchers now feel our understanding of the situation is. Perhaps now would be an appropriate time to solidify debris reduction policies in a treaty. But my gut feeling is no. If the present policy regime is effective, that is if spacefaring nations, agencies, companies, etc. are following the recommended policies and living up to them, I would prefer to keep the situation on the present level, so that engineers and scientists can have flexibility to recommend changes if their research indicates new hazards or potential improvements in ways to avoid generating space debris.

What would be useful, in this country anyway, is to budget more money to study the space debris situation. What I keep hearing, from my friends and acquaintances who are still in the field, is that most serious players in the space business agree that orbital debris is a serious problem that very much needs to be studied. But in a time of tight budgets, everyone wants someone else's department or program to pay for the research, not theirs.

We can ask our congress people to vote for more money to study the orbital debris problem. <LJF>

I occasionally wonder how long space settlement will remain in a state which might reasonably be defined as "early," "primitive," or perhaps "pre-robust" once the great adventure has begun. Barring amazing breakthroughs in technology (or, at least, amazing breakthroughs in popular mood and interests) I think it is fair to say that the space frontier will be a much more challenging frontier than any other humans have yet faced. It is not only a more challenging frontier to get settlers to, but it is a more challenging frontier to merely survive on, to say nothing of building a thriving culture. Additionally, it is a more challenging frontier on which to build a functioning and flourishing economic infrastructure. Considering all of that, it seems likely that space settlement will remain in a vulnerable, non-robust, "primitive," "early" state for at least forty years, and possibly as long as a few hundred years.

Once human expansion in space has entered a robust and flourishing state it will be able to solve any problems it is likely to face on the fly. We needn't worry about anticipating and trying to prepare for those problems. They are *no* concern of ours except for science fiction entertainment purposes. That is not what the current space enthusiast movement, nor this column are about. When I write these columns my concern is with those things which might hinder or promote the early stages of space settlement, those things which could possibly result in a temporary or permanent death to space settlement, those things which might prevent or reduce the likelihood of such a negative outcome and those which seem like they might help advance the current of space settlement on to a more mature and robust stage.

I also try to give consideration to the problem of how we might get from where we are right now (stuck here on Earth), to where we want to be (starting to irrevocably settle space). The other fundamental guiding concern I try to address is how we can arrange things so that we, ourselves, or at least people like us can be included in the great challenge and adventure, and not just money bags, PhD's, the prettiest of the muscle bound, and folks of the far future.

Maybe I'm wrong ... maybe most space enthusiasts are convinced that the space frontier will be so quick and easy to settle that the only hold up is the public will. Get the public in line and we'll all be living in space in a matter of months. Or maybe most space "enthusiasts" actually don't really care if space is ever opened to settlement. Maybe they just like to be part of a fantasy. Or maybe they don't really want to go, don't really want anyone else to go,

and don't really want to do anything which might actually promote an irreversible opening of the space frontier to settlement. Maybe I am just deluded, or have misunderstood the situation, or am just plain on the wrong track altogether.

Maybe, but since I am convinced that is not the case (though I realize that I probably only have the foggiest sense of how things might really turn out to be) I press on in hopes that I might add a little bit to the ultimate success of space settlement and perhaps even hasten the course of events.

Who will go? How will they live?

However, if space enthusiasts really *do* want to be able to go themselves, if they really *do* want people like them to be able to go, and if the settlement of space, rather than being a cake walk, will be tough and trying, expensive, slow to mature to robustness and so forth, then for a long time (in terms of human lifetimes) there will be unavoidable limits on who gets to go. If those assumptions are correct, then we are confronted by some tough, inevitable, unavoidable questions.

What characteristics and/or circumstances should disqualify a person from going? What characteristics and/or circumstances should make a person more qualified to go? How should lists of positive and negative characteristics be determined? Who should get to make these kinds of decisions?

How will people "make a living?" Will settlers be given the bare necessities but no pay? Will they be paid and in turn have to purchase the necessities or die? Or will there be enough wealth to provide the necessities and some level of payment as well? How will expenses like transportation from Earth to the space settlement be paid for?

A Business Plan is Critical

"This is the first frontier faced by humans which is unassailable without a business plan."

The list of *fundamental* questions goes on and on and on, making it clear that this is the first frontier faced by humans which is unassailable without a business plan. And it not only requires a business plan, but it demands a superbly crafted, unerringly reality based, absolutely comprehensive business plan crafted to a finer level of detail over a broader scope than any that has ever been seen before.

Clearly, making the plans for the first few space settlements is a monumental task. But it is not an impossible task. The common person now has access to unprecedented and astonishing computing power. And through that computing power and advances in communication systems they also have unprecedented communication and networking power. These are not only advantages for people, but they are also advantages for data sets (such as busi-

ness plans). That is to say, regardless of who is working with data, the "system" which includes the data, the people who are trying to achieve some result, and the hardware and software which connects the two ... that "system" is now far more capable of generating far more complex and inclusive patterns (i.e. results) than has ever been possible in the past and for far less cost.

The Human Factor

The greatest bottleneck remaining is the "human factor." The "human factor" includes such things as insufficient motivation, misguided and/or misdirected motivation, lack of vision, unrealistic vision (both too negative or too positive), and lack of resources. Consequently, planning has to start with an accounting of current resources, an assessment of reality (what is possible at the current stage), and the development of a plan which utilizes only the currently available resources under the currently imposed circumstances of reality to access a greater breadth of resources and create a greater set of possibilities to be utilized in the subsequent reality.

It is usually advantageous to make preliminary outlines of plans for later stages based on the anticipated resources and reality expected to result from current and future progress. The problems, wasted resources, frustrations, burnout, and all too often, failures come from allocating too much time and energy spent speculating on, dreaming about, and constructing detailed plans and expectations for later stages while not allocating enough time, energy and resources to the details of the current steps.

It is only useful to tackle nearer term problems

Because our goal is so lofty, so complicated and so expensive it is an ever present temptation to fall into this tar pit and waste our time trying to solve the problems of the 20th generation of space dwellers, or neglecting critical but annoying or less interesting nearer term problems, or even trying to solve problems which don't actually exist. The 20th generation doesn't need our help! It is the pre-immigrants, the first immigrants and the next generation or two who need all the brain power we can give them. Critical problems need to be addressed whether they are not interesting to us or not. And we just don't have enough resources to waste our time solving problems which don't exist.

There are various groups, publications, etc., which are making a good start at sorting things out and chipping away at figuring out how we can get to, and live permanently, in space. I commend them. Yet it seems that there is still room for a fundamental reevaluation of the whole problem: who will go, how they will be selected, what they will need to get there, how to obtain the means to get there, how they will live there, how they will get what they need to live there, etc., etc., etc.

<RRR>



As important as the Equipment may be, the most critical element in the successful opening of the Space Frontier will prove to be the people and their spirit. Of this there can be no doubt, there are still in this risk-averse age, enough people with the right stuff to make it happen. We will never forget those who have gone before, and braved every risk - *because they believed that it is worth it. We shall not forget! We owe it to them to continue!*

Space Frontier Foundation Urges "Incredible Quest" to Continue

Nyack, NY, February 1, 2003 - The members of the Space Frontier Foundation offer their condolences to the families, friends and co-workers of the brave crew of the space shuttle Columbia, STS 107.

"These people were heroes of the highest order," stated Rick Tumlinson, the Foundation's Founder. "They, like all of those who reach for the stars, shared in a dream that will not die. The opening of the space frontier is the ultimate calling of our time, and those who answer that call are heroes. We call for America and the world to not give up on this incredible quest."

"Those of us in the space community have known since Challenger that accidents will happen on the edge of any frontier," stated Tumlinson. "That doesn't diminish the sorrow, but instead reminds us of the importance of this work, and the greatness of the people and institutions that have taken it on for all of us on planet earth. Instead of deterring us from the work, it should spur us on."

He concluded: "Now is not the time to talk of the hows and whys of this tragedy, as investigations have already begun by those whose job it is to understand such things. In the end, findings will be made and conclusions brought to light and a discussion and debate can be had as to what our next steps will be. There is little to say right now other than to praise the lost heroes. Our greatest tribute to them is to continue their work and never falter in our commitment to realize their legacy."

"Our hearts go out to the families of this brave crew, and their co-workers at NASA. There are no words that can adequately express our sadness." <SFF>

The Men and Women who will go to the Moon

by Peter Kokh

The Columbia Tragedy fresh in my mind, I thought it would be a good time to talk about the Men and Women who will go to the Moon. For the faint of heart, it makes no sense to "send" people into space. They fail to see that space is a frontier that beckons people to "volunteer". As important as is the technology we need to travel in space and safely reach the shores beyond, and the technologies we will need to support our continued presence there, it is the people and the stuff that they are made of that will always be the most critical element.

That the Shuttle blew up was a "Disaster of the First Kind." That we lost seven dedicated human beings is a "Disaster of the Second Kind." That it should lead to a cancellation of the Manned Space Program, both Shuttle and ISS, would transform and magnify it immensely to a "Disaster of the Third Kind." It's all about People in Space.

Astronauts & Other Trailblazers

At this stage of the game we are talking about astronauts and mission payload specialists, a handful of political VIPs (to up the odds of favorable budget resolutions), and less than half a handful of "tourists." There are many reasons to go to space, to be in space. Volunteers are *sent* to work, to experiment, to discover, to assemble, to test. They *volunteer* to help push the boundaries of science, to lay foundations for those who will follow, but also for the thrill of boosting up, the thrill of swimming gracefully in zero-gravity, the thrill of gazing out the shuttle windows at the beautiful Earthscapes below, the thrill of seeing clusters of city lights over Earth's night side -- the privilege, in short, of being among the first and the few.

In time others will go with more mundane brick-laying tasks: providing commercial in-orbit services to the Space Station(s), building Tourist "Orbitels," reporting for the media, auditing, etc. And, we expect, just plain tourists themselves, people willing to spend good money for an unforgettable and "priceless" experiences and memories.

The First Lunan "Returnees"

Soon after we begin taking tourists into orbit for extended stays, we will start provisioning and refueling the vehicles that brought them up from Earth for "loop-the-Moon" (no landing) overflight tours skimming over the farside of the Moon. But that could happen well before the first humans return to the Moon's surface to set up a permanent shelter there to support a continuing presence.

Most of seem to take it for granted that the early days of the Lunar Frontier will see individuals go for short tours of duty: high pay hazardous duty assignments with regular rotation and replacement. But there is good reason

to work to break that mold. In MMM # 91, December 1995, "Personnel Requirements" we wrote (abridged):

www.asi.org/adb/06/09/03/02/091/personnel.html

"There are several reasons why personnel may rotate at a slower rate than the rhythm of Earth-Moon support and resupply flights might seem to allow:

1. not bringing replacement personnel frees up allowable net payload mass for extra badly needed equipment.
2. not returning personnel makes room for extra "export" cargo from the Moon:
 - a. lunar liquid oxygen for delivery to LEO to refuel the Earth-Moon ferry
 - b. loads of regolith samples for delivery to Earth's surface where ongoing processing experiments can be done more cheaply and more thoroughly, i.e. with lower gross man-hour support costs, in better equipped labs
3. if the lunar descent vehicle is built as we've suggested, with the crew cabin under-slung and equipped with a surface locomotion chassis that can be winched to the surface and taxi to the outpost, every descent module that returns crewless means an extra surface vehicle at the disposal of the outpost.
4. In general, average on-the-Moon labor support costs will come down as the amount of productive man-hours per ticket of passage goes up.

[snip] With all these forces operating to encourage extension of lunar surface duty times, outpost managers, both on site and on Earth, will be motivated to provide *perks and incentives for voluntary extension of planned tours of duty*. Moon duty will be exciting and prestigious at first, with no shortage of volunteers. But as duty time wears on, the view out the window less dominated by Earth, more by sterile, barren, unforgiving, and lonely moonscapes of colorless grays, lunar base personnel will be glad to get out of their sardine can quarters, be relieved of their cabin fever, and return "home."

Among the likely perks and incentives: money, the worthwhile-maker, import credits, time off, larger personalizable quarters, flextime, "plus paid" art/craft experiment time, chore rotation (time in the "garden"), eligibility for desirable excursions, etc.

[snip] From this humble beginning to an era when men and women will come intent upon staying the rest of their lives is a tremendous jump. Yet the long road from limited mission scouts to pioneer settlers starts right here, with the need on these several counts to encourage voluntary, but still not indefinite, extensions of contracted duty time.

Our humble lunar outpost will have to number more than a hundred before there is enough diversity of talent, occupation, opportunity, and social interaction to make indefinite stays tolerable even for the hearty few.

The Growth of the Tentative Luna City

Gradually, the biologically assisted life support system will begin to take on the trappings of a veritable minibiosphere, providing a satisfying new cradle for the displaced people from Earth. As this ecology grows ever more massive and self-sustaining, the need to be cradled by Nature will for some be satisfying enough. The need to return to the lush green hills of Earth will subside.

We will have begun to manufacture a visibly large portion of our needs on location, particularly expansion shelter and furnishings. Thriving indigenous arts and crafts will begin to endear pioneers to their new would-be home and start to add to the list of things they would have to "give up" were they to return to Earth. When this list becomes personally more cogent than the list of still missed things they gave up to come to the moon, the balance will be tipped. More and more people will choose to linger on, putting off their eventual return to Earth.

Expatriate Terrans

In every period of history, there have been people engaged in trade or other business, who have lived "abroad" in "foreign" lands for "indefinite" periods, yet who have never surrendered "citizenship" in the land of their birth. In our own national experience, some Americans have lived indefinitely in France and elsewhere in Europe, in Japan and the Philippines and other Asian nations, in Mexico and the Caribbean and elsewhere in Latin America. Among them are artists and entertainer, educators and writers, soldiers and their families, diplomats, and, of course, businessmen.

For many who arrive in the new country on business of one kind or another, there will be some months of acculturation before one's mood swings from homesickness alternating with the excitement of experiencing new things, to a state of comfort and ease in the new "temporary" location. This transition will be smooth, quick and easy for some, difficult and slow for others.

Living in a new land for a significant period, yet never forsaking their homeland and eventual return, never embracing the frontier in a way that takes ownership and surrender, many will come to "work" on the Moon without any intention of becoming pioneers, even though their activities may help the "pioneering process" considerably. Some, arriving on temporary assignments or tours of duty will voluntarily "re-up" or agree to extended stays for the financial benefits of high pay, anticipating more comfortable retirement someday back on Earth. These "Earth-lubbers" will religiously maintain muscle tone in special gyms to facilitate ease of return to Earth's high gravity which would otherwise quickly cease to be something "natural" for them,

Yet it is predictable that most expatriates will begin to feel increasingly "at home:" familiarity, second nature responses, positive anticipations, enjoying the local

music, songs, art, cuisine, local jargon and colloquialisms, comfort with the pace and the rhythms of life and the Moon's dayspan/nightspan cycles. At first unfavorable comparisons with the greater diversity, variety, and sophistication of "things back home" will slowly give way to a self-surprising respect and appreciation for what the pioneers have been able to do within the economically imposed discipline of strict reliance on what they can provide for themselves using the resources they have learned to recognize, tap, and use on the new frontier.

They will have stopped mentally translating prices from Tanstaaf's to Dollars or Euros, from Lunan sunth dates and clock hours to standard Earth-style month dates and the clock times of their homeland time zone. They will have stopped checking new shops in the hopes of finding goods that were commonplace on Earth. They will have made the transition from visiting tourist to resident expatriate. Yet they will have done so, never losing yearning for the scenery, the sports, the celebrations, the music, and the food specialties of "back home"

To be sure, some expatriates will be more sheltered from the slow seduction of the frontier, by virtue of living closely together with other expatriates. This is the usual case for military personnel and for corporate staffs who often live in physical and cultural "exclaves" of the "home" country. But in their daily or periodic sorties onto the streets of the frontier, they may be absorbing more than they realize. Seeds will have begun to sprout and take root.

"Home" is in the head -- what we call "home" is our own sense of "the place where we feel "safe," grounded, secure, whole, relaxed., able to be wholly "oneself."

The expatriate "temporary resident" of the space frontier will arrive with an unspoken, taken-for-granted identification of "home" with Earth or, more likely, some part of the home planet. This unexamined identification may continue indefinitely, even though there is a slow, unsuspected extension of some or all of those attributes of "home" to the new frontier. For some expatriates, the balance of yearning and satisfaction will eventually tip in favor of all that the new frontier has to offer. But for others, this climax of acculturation will never arrive

The test may come on a trip "back home" in which for a moment there is a happy indulgence in all the things one had left behind. Some will feel so "completed" by this cultural reunion as to want never to return to the frontier, or to return only long enough to tie up loose ends.

But for others, this momentary reunion with the sights, sounds, tastes, and experiences of "home" will give way to an unexpected yearning for the sights, sounds, tastes, rhythms, and experiences of the frontier. For them there will be a sudden realization that they have come to belong to the new "home world." One has become more than accustomed to the idiosyncrasies of the new frontier, more

than just "at home" with them, "attached" to them. The new shoe has become more comfortable than the old one. On the trip back to Earth, one kept comparing sights, sounds, tastes, textures, expecting a healing reunion with the old, and discovering instead that the "old thrills were gone," that the usually rougher, cruder, less sophisticated sensory fare of the frontier were now closer to the heart in a way, or to an extent, one had not realized.

More significantly, one may have found one's reunion with the folks back home turned out to be unsatisfying, shallow, less than fulfilling -- "one can't go home again!" The expatriate suddenly realizes that personal bonds of affection, identification and sympathy with causes, was stronger for those on the frontier than for those back home on Earth. One had become part of the new frontier community without realizing it. It took the trip back home to reveal the slow, quiet, never-given-a-name switch on the subconscious level.

For some, such an awakening will have all the manifestations of suddenly realizing that one is "in love." One has been surreptitiously won over to the pioneer mindset without realizing it to the point of saying, "Good Lord, I have become one of them!"

The expatriate will have crossed over.

Lunans: First True Space Frontier Settlers

First the scouts, then temporary crews, then some who volunteer to stay on for a while. The logical progression would seem to be that some would choose to stay indefinitely. But there is a big catch. Socialization (dating, relationships, marriage, and eventual pregnancies carried to term, child-raising on the Moon) has to have official sanction by the powers that be (agencies or corporations or some other policy-making authority) before a real permanent population can develop. In "Native Born," MMM # 47 July '91, I argue that we must take the plunge here. We cannot know for sure that native born Lunans will be fertile and without serious health problems until we have adult native born Lunans. Demanding that we have proof ahead of the evidence is absurd. Yet we could expect conservative agencies like NASA to be aghast at the prospects. Indeed, if we are to have settlement, a civilian authority, with local autonomy must be in charge.

Given no ban on relationships, it should not be assumed that the first to become settlers will be those who came on a temporary basis and simply never went home, getting gradually accustomed to life on the Moon. The history of frontiers on Earth gives ample evidence that there is a *cross-section of any population* which is willing to take the risks, even forsaking the possibility of ever returning, for a chance to start life over, to get in on the ground floor for a change, to have a chance to live a life with real significance and deep rewards, however harsh, whatever the sacrifices, no matter how many rough edges,

There is Daylight on Mars!

by Peter Kokh

The first true pioneers, those who came intending to stay, will be a self-selected group. They will be bright, creative, resourceful and talented. But perhaps not the most so. Those who fit in just fine will be content to stay where they are. Frontiers are pioneered by "the second best" -- those not quite good enough to make it to the top of the pile in the status quo rat piles on Earth. Even in nature, it is capable animal populations who couldn't quite compete where they were who pioneered new territories and new niches. If Nature has Beatitudes, "Blessed Be the Second Best" must surely be among them.

These will be men and women who want a chance at a significant life, not necessarily a comfortable one. It is amazing to me that so many devotees of science fiction and of the imagined space frontier are attracted to the image of a life environment in which things are better and more advanced and sophisticated than here on Earth. The frontier will be just the opposite. A place where things will be rough, where there are always too many things to be done by too few people, where too many "favorite things" and creature comforts must be left behind. The frontier will be a place with rough edges. But there will be priceless rewards of the spirit in enduring them, in helping to make things better. The good life on the frontier will have to be won. The pioneers will be those who do not shrink from having to work for it, to fight for it, to forge it.

Occupations:

All talents will be needed on the frontier. Those who will create the essential infrastructure will be (in no particular order) architects able to work with building materials made on location, pressurization engineers, ecologists, hydroponics experts, soil-farming experts willing to work with regolith, cooks able to create satisfying cuisines from much less a variety of ingredients, sports "architects" who can design team and individual sports that are exciting to play in one sixth gravity and exciting to watch, choreographers who can pull off the same stunt in dancing, artists and craftsmen willing to forget about the media they are used to using on Earth and willing to experiment with local materials and byproducts. Without these, all bets are off.

But we'll also need just about every other kind of profession and occupation to keep it all running. The bottom line, the "sine qua non," is the desire to start over from scratch, if not the need to do so. It won't work with people who go with a "I'll try it, and I'll stay if I like it" attitude. They will be too easily discouraged by setbacks and hardships and sacrificed, too little rewarded by hard won successes. Frontiers are settled by those willing to leave the home setting without ever looking back. Such people may seem rare, but history proves that there are more than enough who will arise to the occasion - every time! If it is true that people with the right stuff are the most critical ingredient needed to establish settlement on the Moon, then we've got it in the bag.

<MMM>

That may seem to be a strange declaration. But in fact, Mars is likely to be the only world in our Solar System where people will walk and live in "daylight." For, despite the Sun shining constantly on the Moon for nearly 15 days at a stretch (the "dayspan"), there is no true "daylight" on our neighbor world to be experienced and enjoyed. The Moon's "skies" are black, not bright blue (or any color). There is direct sunlight but no *ambient* daylight, light scattered from all directions, such as we experience here on Earth. Indeed, the Moon has "heavens" but not a "sky."

Mars, on the other hand, has a real sky. Yes, it is not blue. Yes, it is only half as bright as our sky. But a sunny day on Mars is significantly brighter than a cloudy day on Earth. This is one aspect of the Mars Frontier that will make it more attractive than the Moon to many.

We wrote about "The Black Sky Blues" (on the Moon) in MMM # 138, SEP 2000. For future Lunans, relief will come in ample "middoor" spaces with brightly cove-lit vault ceilings, possibly sky blue in color, and possibly similar ceilings in private residence structures, hallways, etc.

Indeed, since most Lunans will live the bulk of their everyday lives within enclosed settlements, not out on the surface, one might be tempted to say, "what's the big deal? The sky is black! So?" Actually, Lunans will have the better nightspan star gazing experiences. Not so during dayspan. The Apollo astronauts, all of them on the Moon only during *midmorning* lighting conditions, found that the glare of the sun makes the stars invisible in the black sky.

But when Lunans travel between settlements and other remote locations, they will never experience daylight. The lunar terrain may be brightly sunlit, but the sky will be black, and almost all the available light will come from one direction, from the sun. There will be some trivial reflected off of sunlit surfaces. Hearty Lunans will learn to adapt.

On Mars, the pioneers will also have to adapt -- but not to a black sky, to a salmon colored one much easier on the eye. They will enjoy full daylight when traveling or working out on the surface. This difference between the Moon and Mars may seem trivial, but should result in some distinctive cultural differences between the two frontiers.

As content as future Martians may be with their color-shifted daylight, future Lunans will be the better able to adapt to similar black sky situations on most other moons and asteroids in the solar system. Besides Mars, only Titan offers a bright sky, also reddish, but much dimmer (1/50th the light levels!) Alas, I'd still miss the blue skies of Earth, and the Arizonesque Marsscapes will seem wrong without them. For a while, anyway!

<MMM>

Keeping the Mars Frontier in the Pink

Solar Sail Cargo “Pipelines”

can greatly reduce the cost and risks of “opening up” Mars as a frontier

by Peter Kokh

The long-awaited Cosmos-1 solar sail mission may provide a big boost for dreams of opening Mars to human settlement. The reasoning is simple. By being able to tack in the solar winds, solar sail cargo vessels can slowly make their way to any destination in the inner solar system without waiting for ideal launch windows, in the case of Earth ↔ Mars flights, some 25+ months apart.

The cargo or payload capacity of a solar sail depends on the size (area) of its sail. Cosmos I is a modest 30 meters (99 ft.) in diameter, but much larger sails could conceivably be built, all of gossamer light materials, using such devices as inflatable tubes and/or rotation to keep the sail taut in its unfurled state. It can “tack” inward and outward against the solar wind much as sail ships on the oceans can tack towards and away from the wind.

Sails made on Earth need to be coated with polymers to be sturdy enough to launch. Selecting polymers that degrade and evaporate in sunlight would help reduce the weight and increase the efficiency. Someday, more efficient sails may be manufactured in space.

About the Cosmos I Solar Sail Mission

<http://www.planetary.org/solarsail/>

The spacecraft is being built by the Babakin Space Center in Russia, under contract to The Planetary Society. It will have a 30-meter (100 ft.) diameter sail, configured in 8 triangular blades and deployed by inflatable tubes from a central spacecraft at the hub. The 100-kilogram spacecraft will be launched by Volna, a submarine-launched converted ICBM, into a 800-kilometer (c. 500 mi.) circular, near-polar orbit of Earth. Microwaves beamed from the 70-m Goldstone radio dish in the Mojave desert will then push it through space.

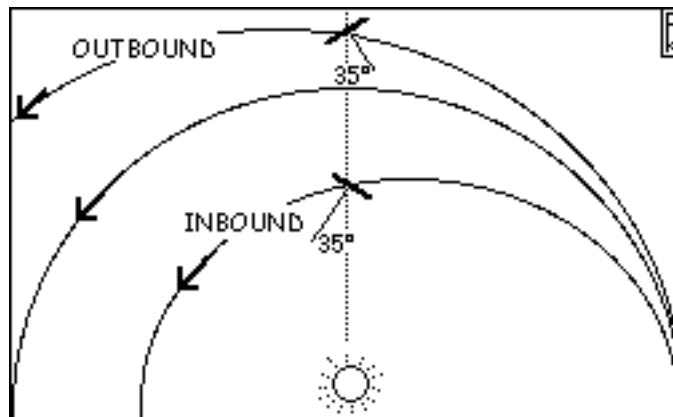
The submarine launch planned for **mid 2003**. will be from the Barents Sea north of Murmansk. The spacecraft will be operated from the Babakin Space Center near Moscow. Telemetry data will be received in Russia and in the United States.

Inflatable tubes keep the sail rigid. The solar sail will use the pressure of sunlight to increase its orbital energy and raise its orbital altitude. The sail is controlled by pitching the blades, thus turning the direction of the solar force. []

The purpose of the Cosmos I mission is to conduct the first solar sail flight and demonstrate the technique for traveling between planets.

Tacking outbound, tacking inbound

Aligning the sail so that sunlight falls on it straight on (perpendicular) is not efficient in orbital mechanics. If we tilt the sail so that the angle between the sun and the perpendicular to the sail is about 35 degrees, we maximize the component of thrust parallel to the direction of travel. This allows the craft to be pushed along the direction of travel, climbing up the gravity well, yet slowing down. By aligning the angle the other way to oppose orbital velocity, sunlight pushes against the direction of travel, dropping the sail down the gravity well and causing it to speed up. Solar sail can travel sunward as easily as away from the sun.



While the original idea was to use the energy of sunlight, quite strong everywhere in the inner solar system, scientists are now considering additional “beamed energy” sources such as microwave beams and lasers. These energy boosters would work to increase cargo capacity and/or shorten trip times. Beamed Energy Propulsion (BEP) is gathering a lot of attention these days, witness the First International Symposium on Beamed-Energy Propulsion held 5-7 November at the Univ. of Alabama in Huntsville. Using sunlight or beamed energy instead of tons and tons of rocket fuel and fuel tanks and the engines themselves, makes this form of transporting cargo relatively cheap.

Solar Sail Cargo Shipments as Infrastructure

Solar or beamed energy cargo sailing vessels, given their ability to take a variety of complex trajectories to their destination, can create a virtual “pipeline” if they are dispatched in sufficient numbers to form a “steady stream” of cargo is always arriving at the destination -- say Mars. While this transportation system would not address any emergency needs of the Martian pioneers, it would be ideal to provide a steady stream of fresh supplies needed on a regular, routine basis for maintenance of the base and staff, and for planned expansion of habitat space, the agricultural areas, power systems, etc. Examples include foodstuffs not yet grown on location, components needed for outpost expansion, agricultural soil amendments and nutrients, fuels which cannot yet be produced locally, clothing items, tools, seeds, replacement parts, etc.

The Great Solar Sale Race of 1992

[Excerpted from]

<http://caliban.physics.utoronto.ca/neufeld/sailing.txt>

The outlook in 1990

The first President George Bush charged a committee with planning events to commemorate the five hundredth anniversary of Christopher Columbus' departure from Europe for the Americas. Among the ideas chosen to be implemented... was the Columbus 500 Space Sail Cup. Spacecraft were to launch on conventional chemical rockets around Columbus day of 1992 and have to go to Mars using only light pressure. Among the serious competitors were the Canadian Solar Sail Project, an initiative of the Canadian Space Society, the Aeritalia Team from Italy, Cambridge Consultants from Britain, and the World Space Foundation from the United States... also teams from Japan, Israel, and the Soviet Union ... Among the criteria for winning, was shortest transit to Mars orbit and the closest approach to the planet. To be recognized as a winner the sail must have received no government funding, but could have received money from the Columbus Commission. One team from each of the Americas, Europe, and Asia, was to receive whatever money became available. The World Space Foundation sail was the official Americas sail, and was receive some of the money ...

In retrospect: The race did not take place. Commercial funding was not available for private launches, and the U.S. government decided not to pay for launch costs for three of the entrants of the race.

How long it will take a Cargo Solar Sailer to get to Mars?

Cargo sailers may take much longer to reach their destination than would chemical rockets. The time will depend on the sail and payload mass relative to the area of the sail, and to the relative positions of Earth and Mars at launch time. But for "routine cargo shipments, all that will matter is that there be a fairly continuous supply at the destination. Time spent "in the pipeline" is immaterial.

How a Cargo Sail Pipeline will Help Open Mars

The advantage to Martian pioneers will not only be in the much greater frequency of shipment arrivals, but also in a significantly lower bill for "shipping & handling."

Solar sailing is attractive as a means of travel between the planets, when time spent in space is not important. The propellant is sunshine, there is no fuel, and the thrust is continuous. In contrast to chemical rockets, solar sail freighters do not have to be 95% fuel by mass.

As the pioneers will be hard put to produce exportable products that will be marketable on Earth, it will be vital for their bottom line to minimize the cost of imports for which they must find some way to make payment. Solar Sail Cargo shipments will thus greatly reduce

the bill for maintaining, sustaining, and growing the human outpost(s) on Mars.

Cargo sailers are not one-use-throwaway craft. With proper trajectories, payloads can be dropped off, and picked up, as the sailer flies by Mars. This is vital, because goods exported to Earth will help settlers pay the reduced bill for imports. Using solar sail freighters to ship items back to Earth will minimize shipping costs, making Martian exports more attractive on Earth. Thus solar sail pipelines between the Earth-Moon and Mars-Deimos-Phobos systems will help on both ends of the Import-Export Equation.

The attractive economics are not the only advantage, however. A solar sail cargo "pipeline" will also provide some insurance against missed launch window opportunities for chemical rocket payloads, whatever the cause of their being missed (technical, weather, political mischief..)

How payloads will be delivered to the surface of Mars is important too, but another question. Aerobraking cargo shuttles, self-landing payloads using parachutes and inflatable pods, are among options to be considered.

What cargos will go by the solar sail pipeline?

The pioneers will be doing all they can with the tools and equipment provided to rely on building materials they can produce locally on Mars, and on other local resources. But as they expand their settlement they will need many components and items that they cannot yet manufacture or supply locally. Along with imports of more and more capital equipment to allow local manufacture of more items on the strategic must-make-locally list, they will need ever more vehicles, appliances, electrical wiring components, plumbing items, water and air recycling systems, vehicles, power generators - the list is quite long.

The alternative: the "yolk sac" strategy

There Mars pioneers will need a continued influx of many common commodities such as fuel, food stuffs not yet produced in outpost farms in sufficient quantity or variety, pharmaceuticals, clothing, etc. But without a solar sail cargo "pipeline" to deliver such items on a "just-in-time" basis, the outpost will need a substantial nest egg (a "yolk sac") of supplies in quantities large enough to provide prudent margins should consumption or accident use up or waste needed items faster than expected. If a dire need develops before the next rocket shipment from Earth (on 25+ month intervals) they would simply be out of luck. Mars is simply too distant for an umbilical cord type of nourishment. [see MMM # 113 MAR '98, p. 6, "Yolk Sac Logistics"]

Yet a solar sail freighter pipeline will provide no relief at all for unexpected emergencies. To maintain & repair critical systems (power, life support, medical, etc. a "Yolk Sac" cache must be "on hand," not "in the pipeline.

That fact has consequences that those who insist that a prior lunar outpost would not help open up Mars in a timely fashion must consider. It would be the height of

presumption to send undebugged, unproved, critical systems to Mars without proper field trials. Some of these systems can indeed be tested in low Earth orbit. But those that rely on gravity to function properly, can be tested with more reliable results, and greater confidence, on the Moon where rescue, resupply, and repairs are only a few days flight away. We don't ask the government to open the Moon first, or at all, but if a commercial Moonbase is in place before decisions about critical equipment to be included in a first Mars outpost, that would take some of the pressure off the need for a burdensomely large cache of replacement parts.

Point of Departure in the Earth-Moon System

For routinely needed parts and goods that can be made on the Moon, sails departing from near the Moon will provide quicker service to Mars than sails departing from low Earth orbit. The climb out of Earth's deep gravity well on sunshine alone, will take months. The Moon rests on the shoulder of that gravity well. Sails leaving from the Earth-Moon L1 Gateway will make the trip that much faster. Thus any early lunar industries making items for use in the lunar outposts and settlements that can also be of use on Mars will help sustain efforts to open the rusty frontier.

If Cosmos I succeeds, what's next?

The Cosmos I mission hopes to test several things: in-space deployment of the sail itself; tacking in sunlight; rates of acceleration etc. We know from bitter experience with NASA tether missions, how disappointing such test flights can be. Failure can come from an unrelated system with the result that nothing at all is learned. NASA's reaction has been to not try again. Cosmos I is the baby of a determined party, however. The Planetary Society understands the crucial value of solar sails to the opening of Mars, a goal to which TPS is committed. Congress, unfortunately, has not allowed NASA to be so committed.

If the flight goes less well than hoped, it'll be back to the drawing boards, with a retest a couple of years down the road. If all goes well, we'll want to do several things:

- testing improved, more efficient sail materials
- testing improved deployment systems
- trial flights to Mars over several windows
- recovery of the sail after Mars flyby
- payload delivery to Mars surface, on target and intact
- test navigation precision
- scaling up the sail to carry helpful payloads

The years ahead promise to be exciting ones for solar sailing. It's been a very long wait, <MMM>

Read More -- SOLAR SAIL LINKS

www.kp.dlr.de/solarsail/

www.spacetransportation.com/ast/abstracts/3C_Frisb.html

www.spacetransportation.com/ast/abstracts/3E_Horod.html

<http://caliban.physics.utoronto.ca/neufeld/sailing.txt>

<http://web.mit.edu/newsoffice/tt/1990/sep19/23638.html>

<http://members.aol.com/dsfportree/AT13.htm>

The Ideal Mars Suit

If we ever would be something more than "Strangers in a Strange Land," we'll need lightweight, Mars-hardy, and intelligent "outerwear" to let us enjoy "the big red outdoors" as if we truly belonged there.

by Peter Kokh

Attitude is Everything

On Earth, those of us who live in winter country, know how to dress to keep warm no matter how cold, how blustery, no matter what the wind chill. It's all a matter of layering. For most of us rugged winter-hardy folk, it's a matter of just keeping warm enough to go about our business of getting from here to there without getting a chill.

That said, many of us would have to admit that while winter is "not a problem," we still do not feel quite "at home" outdoors in that kind of weather. But there are those who have transcended to that point of comfort, thanks to lightweight winter "sportswear" flexible enough to allow full free movement of arms and legs. It is the winter sports people, and their outfitters, who have found a way for people to feel quite at home outdoors in weather that our less hardy sunbelt countrymen would find nothing short of Antarctic.

NASA did an excellent job of designing the Apollo Moonwalker suits, again relying on layering to provide micrometeorite, radiation and thermal protection, along with pressurization and life support. The suits were big and bulky, but they allowed us to get around, clumsily, and get the assigned tasks done. The Apollo suits provided a personal micro-environment that allowed us to explore an alien environment that would have been instantly fatal without the protections they afforded.

Compare those suits to the first early diving suits, or (why not?) to the aquarium "suits" that fish must "wear" to survive in our air-filled living rooms. "Strangers in a Strange Land" - SISL. SISL suits are good enough for exploration perhaps, but not for pioneers that want to be able to go here and there in their adopted homeland "as if they belonged," in a way that protects but yet allows full freedom of movement without fatigue. Lunar "Out-Vac Sportswear" will appear when there is a market. Pioneers who volunteer to settle the Moon, but who are unwilling to check their love of outdoor sports at the door of the launch pad on Earth will create that market. In time light, flexible, yet still fully protective suits will be available that will let future lunans fill truly at home engaging in a wide variety of out-vac sport activities.

The SISL mentality will likewise produce suits for Mars Explorers that will be adequate for all the tasks that mission control assigns. But, again, in time the market for something better, much better will appear.

Anticipations of Martian Surface Sportswear

One place people are already working to design a "better Mars suit" is in Australia. We first reported on Mars Society Australia's "Marsskin" Project in MMM #150 NOV. 2001, p 15. Mars Society Australia Projects. See:

www.marssociety.org.au/marsskin.shtml

The Apollo suits, and all space suits used to date by both astronauts and cosmonauts are of the gas-pressurization type. They work, and have been amply tested in the field. But they have stiff joints which fight the wearer's efforts to bend them. And they are bulky. Moreover, by containing an atmospheric shield that envelops the whole body of the wearer, they greatly increase the chances that a puncture of any part of the suit will be fatal.

In 1967, Webb and Annis published the concept and early experiments of a Mechanical Counter Pressure Suit (MCP), and in 1971 described the first demonstration of the many advantages to the MCP approach which exerts pressure on the body using formfitting elastic garments.

MCP garments offer dramatic improvements to gas pressurized suits *in reach, dexterity and tactility due to the replacement of stiff joints and bearings with light, flexible elastics, lower suit costs and vastly reduced weight and volume.* And, they are *safer*: a tear or hole would remain a local defect rather than cause a catastrophic puncture. . MIT flexibility tests in the mid 1980's found MCP gloves to be notably superior to gas-pressurized ones. Since then there have been major advances in textile technology for fibers, yarns, and automated knitting machines.

Mars Society Australia's Project MarsSkin aims to design, produce and test analog mechanical counter pressure (MCP) space suits to be used in Mars analog research projects undertaken in Australia and internationally. They will behave in a near identical fashion to the real MCP suits which may one day be worn on Mars.

Meanwhile, NASA-supported research into MCP suits has become another victim of the budgeteer's ax.

The U.S. Army's new "warwear" - (as shown on ABC's "Good Morning America," 2/26/03) includes a handsfree drinking tube (reminiscent of Fremmen Stillsuits for all you Dune fans) and a handsfree radio that uses your skull bones as an amplifier, and a walkie-talkie GPS combo.

Military needs are akin to the needs of the sports-minded, in that performance is paramount. The wearer must not be encumbered in any way. To the contrary it is important to give the wearer every possible tool to be able to comprehend, analyze, and negotiate his/her "alien" environment to advantage. A proper Mars Suit (or Moon Suit) just as a battle suit, needs to be a smart one.

What "smart suit" features will help us on Mars? One can conceive of a "dust storm visor shield" that would automatically slide over the helmet visor when a certain threshold of airborne dust was reached, paired with a shield-activated visor heads-up screen on the visor that

would use radar (and infrared and/or whatever can penetrate the dust?) to create a useful live picture of one's surroundings good enough to navigate by. Such a dust shield and enhanced view screen will be a miniaturization of what will be needed on Mars vehicle "windshields."

Infrared heat sensing vision will be important in search and rescue, in finding cave entrances (shelter) and even in prospecting (highlighting minerals that either retain heat longer or lose it faster than the background, minerals that heat up faster/slower than the background.)

In dusty or overcast sky situations where the direction of the sun is not apparent, and where the terrain seem monotonously the same in all directions, it will be easy to lose one's bearings. As Mars lacks a magnetic field, a compass will be useless. A satellite network GPS system will help determine position. But not necessarily direction, until one moves enough in some direction to make a noticeable change in position. Or can the GPS be configured to reveal direction as well?

We wrote about "Engaging the Surface with Moon Suits instead of Spacesuits" in MMM # 151 DEC 2001. In that article, we discussed a number of useful smart suit features such as monitors that would keep the wearer informed of straight-line distance from base or vehicle and minutes of life-support remaining before safe return to base or vehicle became marginal.

But while the first explorers will definitely benefit from any improvements offered by the improved space suits of the time, for the pioneers themselves, those intending to spend the rest of their lives on Mars, the difference between a suit that will make them feel "at home" out in the open and one that will merely keep them safe, is critical -- critical to the overall morale and mood of the settlement population. Feeling safe, but still "a fish out of water" will do little to reinforce their decision to stay and make a new life in a new niche for mankind.

NASA and other government agencies involved in the effort to explore Mars are likely to prioritize "some" space suit improvements. But the budget ax will fall on other worthy improvements. Nonetheless, the explorers will make do and "succeed" in their explorations.

Yet we in NSS, the Mars Society, the Planetary Society, and even the Moon Society seek to go beyond exploration, beyond another series of science picnics and temporary encampments. Our vision is not that of the explorer or scout. It is that of the settler, the colonist, the foresaker of an Old World, of one committed to a fresh start in a virgin land, willing to learn the ways of that land, determined to "become a native" to the extent that such a seeming contradiction in terms is possible.

It is our efforts, spearheaded by MS Australia, and eventually championed by commercial outfitters of frontier sportsmen, that will make it possible. <MMM>

Need for More, Diverse M.A.R.S. Habs

by Peter Kokh

The Mars Analog Research Station designs in use on Canada's Devon Island in the Arctic and in the south central Utah desert are based on Robert Zubrin's "twin tuna can" Mars Habitat designs featured in his "Mars Direct" mission proposals. Both are two story structures supported on legs used for landing the habitats on site. The new EuroHab version is the first one to tweak the original design somewhat. Making it "a tad taller" gives just enough room to squeeze in three floors (with reduced ceiling height) and therefore 50% more floor space. One of the positive things to come out of operations in Iceland, where this hab will be deployed soon, is an analysis of the affect this increased roominess will have on operations, both directly by making room for more apparatus, and indirectly, by its affect, if any, on crew morale.

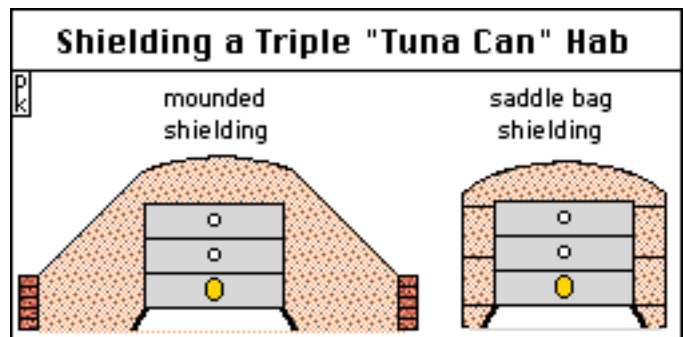
The 4th M.A.R.S. Hab will part company with its predecessors in using a pre-Mars-Direct design, the so-called Biconic shape for a habitat "flying in" for a landing rather than lowered to the surface vertically by parachute.



http://www.marssociety.org.au/technical/tech_images/MarsOz_cover.jpg

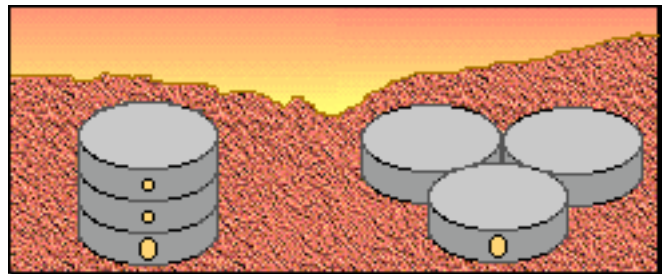
While the pros and cons of landing the two basic designs cannot be tested in Australia, the relative effectiveness of the two designs in supporting operations can. The biconic design has the advantage of a lower profile, which will make it easier to shield with loose Mars regolith soil. In fact, it would be feasible to test various methods of robotic or teleoperated shielding emplacement in Australia. We do not know if that is one of their intentions, We do know that the need for shielding is a concern dismissed by Zubrin, both for the duration Mars explorers will be on the surface (30 days to more than a year, depending on mission profile) and in transit in spaces. An unfortunate attitude.

Shielding ease and methods are things we can pretest and pre-debug without spending a lot of money, and therefore should be one of the goals of the M.A.R.S. Hab program. There are ways the higher profile twin or triple tuna can design habitat (even with legs) can be shielded. A large mound with sloping sides can be bulldozed or otherwise moved in place. This mound would involve moving a considerable amount of soil. Starting with a perimeter ring of blocks sintered from packed soil, or of bags filled with soil, several rows high would help constrain the diameter of the mound necessary.



As shown in the illustration above, using fabric "saddle bag" held in place by straps to the habitat hull, and folded in pleats against the hull for the transit from Earth would reduce the total volume of soil needed as well as the footprint area of the shielded habitat. Both methods could be tested, and tweaked, on location in Utah.

It would seem, however, that the tuna can stack has disadvantages. Not only does the high profile complicate shielding emplacement, but it sacrifices volume to a ladder well. In Utah or another location, an "unstacked" version, in which all three separable floors are hoisted off the landing feet and onto a prepared flat soil bed, might have advantages. Access between units would be direct through doorways 120° apart. And with the lower profile, shielding might be much easier, as well as adding expansion modules sometime in the future.



Perhaps all these experiments will reaffirm the choice of the stacked hab concept. There'll still be a need for additional testing. Zubrin's design is ideal for launch on top the external tank of a shuttle derived launch vehicle. Thus its 27 foot diameter. But by choosing an inflatable version, to fit uninflated inside the 15 ft. wide shuttle payload bay or in a same size faring on top of an expendable vehicle such as Titan 4, Delta 4, Ariane 5, Proton, etc. would help insulate Mars Mission plans from the uncertain future of shuttle-based systems. NASA's aborted TransHab project with similar 27 ft. diameter and 3 floors, could be resurrected. Meanwhile, a faux-inflatable stacked M.A.R.S. Hab with a TransHab like interior architecture would serve to test the ergonomics and effect on operations performance of such a design.

These suggestions do not exhaust the options, but if pursued, would provide invaluable experience and confidence in the appropriateness of the design chosen for the first Manned Mars Mission. Meanwhile, we support and follow the M.A.R.S. Hab project with enthusiasm. <MMM>

The Interlunar Cycling Station: Traveling First Class

by Dave Dietzler <pioneer137@yahoo.com>

There's a right way and a wrong way to do everything. Traveling to the Moon in small ships made from external tanks with spartan accommodations will be okay with adventurous travelers in the early decades, but some day we are going to need something better. Those E.T. ships are rocket fuel guzzlers. Nuclear electric propulsion with ion or VASIMR drives looks like the answer.

Well, that's the wrong way. The Moon has plenty of magnesium for electric drives; however, the problem is the low thrust of electric drives. It will take weeks, perhaps months to spiral out of LEO and reach the L1 point or lunar orbit. The crew and passengers will die due to Van Allen Belt (VAB) radiation unless the ship is shielded to an absurd degree. A bigger power plant will get us more thrust out of those electric drives and get through the VABs in a few days, but we will still need heavy shielding and our travelers will endure some minor radiation exposure. This will be very bad for the crew that must endure repeated passages through the belts and accumulated cellular damage.

The best power plant would be a vapor core reactor with MHD that produces two, even three, kilowatts per kilogram of total system mass-that includes radiators, pumps, etc. Research into this type of system has been done at the Innovative Nuclear Space Power Institute of the University of Florida [1]. Even so, the power plant must be enormous to produce the energies needed to push a ship carrying about 500 passengers through the VABs in just a few days. When you add up the shield mass and the power plant mass there's only enough left for rather spartan accommodations in the ship like sleeping closets instead of cabins, no "artificial gravity," shared bathroom facilities, less volume per passenger than was on the MIR and general cramped, less than luxurious conditions. The ship mass becomes so great that the use of efficient NEP doesn't reduce propellant demands very much. NEP is ideal for ships bound for Mars that accelerate slowly out of GEO or the L1 port because they don't need so much shielding-just a solar flare shelter, and they can take weeks to escape from Earth orbit and leave the drive on continuously for weeks to reach high speeds and shorten travel time to Mars. For interlunar luxury liners we need something entirely different -- the cycling station.

The cycling station will be very large. It will be propelled onto its orbit once and never again need but a tiny bit of propellant to make course corrections. "There ain't no such thing as a free lunch," but the cycling station comes close. Taxis will be necessary to reach the cycler. Since

these vessels will be small and only capable of carrying passengers for a few hours at most, they won't guzzle much rocket fuel and oxidizer. A cycling station that swings around Earth at an altitude of 500 km. (310 mi.) and rides out to 469,526 km. (292,000 mi.) will have a period of 13.66 days or half the Moon's sidereal period of 27.32 days. Twice a month it will swing around Earth at 10.689 kps. (23,900 mph) and at apogee roughly 470,000 km. (292,000 mi.) out it will be creeping along at only 0.1545 kps (345 mph). Once a month, on every other orbit, it will enter the vicinity of the Moon. When it rounds the Earth, taxis in LEO will fire their motors and catch up with the cycler. The taxi will dock with the cycler and passengers will transfer to the cycler. At or near apogee they will return to the taxi and ride over to the L2 spaceport station. From there they will descend to the surface of the Moon in rocket powered shuttles. Several cyclers could allow Moon travel at various times of the month. The ride will take about a week.

Aboard the Cycling Station

The station will rotate to provide "artificial gravity" and have roomy cabins with private bathrooms rather than just bunks or sleeping cubicles and unpleasant vacuum toilets. Passengers will sit down to normal meals eaten with a knife and fork. Cooks will enjoy their art with the benefit of weight. Space sickness will be averted. Medical emergencies will be easier to handle with patients who don't float off the operating table. The station will hurtle through the VABs in just hours. Nobody will endure even the slightest increased risk of cancer. There will be no complex nuclear power plant that requires costly uranium and extensive maintenance. Environmentalists will not go on the warpath and tie the company up in law suits lasting years because of nuclear reactors in LEO. In a country where juries award \$45 million settlements to people who spill coffee in their laps, this is a real problem.

The cycling stations could be made of [Space Shuttle] External Tanks connected to form a rotating ring. There will be dining rooms, game rooms with ping-pong and pool tables, coffee rooms, bars with beer on tap, dance floors, maybe even a small swimming pool and garden. There will also be weightless rooms in the hub and a small observatory. Cabins will have king sized Murphy beds, flat panel TVs, and other features common to terrestrial or lunar hotels including a bath with running water. A system of antennas throughout the station linked by coaxial cable that connects with a comsat linking radio transceiver will allow cell phone usage aboard the cycler.

Propulsion of the cycler into its orbit will be done with efficient solar electric drives over the course of several months, and at most, a year. Some small aluminum and LUNOX (lunar oxygen) rockets will also be used. After the cycler is situated in its orbit, it will use the solar electric drives and Aluminum/LUNOX rockets to make minor orbital adjustments. Lunar flyby will affect the cycler's

trajectory in ways that I cannot predict, thus course corrections will be needed from time to time.

The taxis will consist of single E.T.s fitted with rocket motors, LSS, etc. Basically, they will be interlunar ships like those described in the January, 2003, Moon Miner's Review #32, refitted with couches for about 400 people. There's a lot of room in one of those E.T.s. It may be possible to cram more people in there, but I tend to be conservative. A taxi will use about 600 tons of Al/LUNOX to rendezvous with the cycler and transfer to L2. Another 600 tons will be needed to leave L2 and retrorocket into LEO on the return flight. Retro-rocketing into LEO seems safer than aerobraking. Three tons of fuel and oxidizer will be needed for each of the 400 passengers. Since it will take about fifty cents worth of electricity to launch a pound from the Moon with mass drivers, it will only cost each passenger \$3,000 for propellant alone -- much less than the cost of propellant for a trip aboard one of those old spartan 50 passenger ships that are now taxis.

When everything is added up the round trip might cost an individual as little as \$100,000! Call it wishful thinking! If the cycling station consists of two rings of 12 E.T.s each and four E.T.s in the hub, for a total of 28 tanks, there will be about 56,000 cubic meters of volume or 140 cubic meters per person with 400 people aboard. The Skylab had 100 cubic meters per occupant. A nuclear submarine has about 70 cubic meters per person and the Salyut station had 50 cubic meters per person [2]. Cycling stations will truly be space luxury liners.

FOOTNOTES:

[1] <http://www.inspi.ufl.edu/index.html> and www.highway2space.com/ast/presentations/7g_knigh.pdf

[2] Marshall Savage. The Millennial Project. Little, Brown & Co. 1994.

NOTE: I used the Quick Orbits program from delta-utec to determine orbital velocities, etc. Also, 28 ETs would amass 925 metric tons, so a guesstimate for the station's mass would be about 2000 tons at most. That's lighter than the NEP liner I tried to design (in MMM #) with its massive radiation shield and power plant. The taxis could use much less than 1200 tons of propellant also with just a small increase in Isp from 250 sec. to 280 sec., but I try to estimate conservatively. <DD>

P.S.: For a previous design study of what an Earth-Moon Cruise Hotel Ship might look like, see the "The Frontier Builder: An Earth-Moon Hotel Cruise Ship: a Definition & Design Exercise" © 1992 Doug Armstrong & Peter Kokh. The authors concentrate on ship design and architecture after discussing the activities that should be accommodated. They also discuss ways to keep the ticket price down. I chose to concentrate on the propulsion question, the one aspect they did not address. Well illustrated. See:

<http://www.lunar-reclamation.org/transitel.htm>

Eclipses: the Lunar Experience

by Peter Kokh

Thursday, May 15th, there will be a total eclipse of the Moon, visible from all of the Continental United States and Hawaii, and from most of the rest of the world except Asia and Australia. For information about this event, go to:

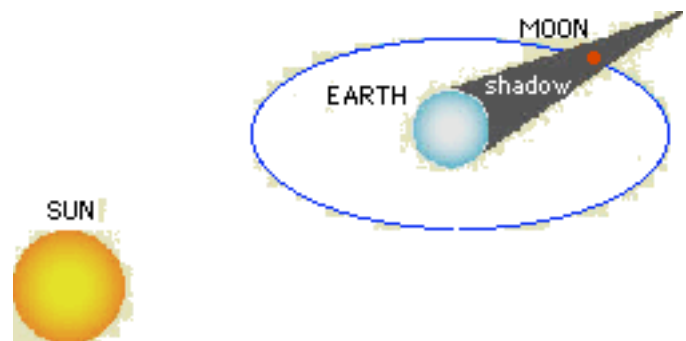
www.netspeed.com.au/minnah/2003/2003-1.html

For an Eclipse Computer that will tell you when (and where in the sky) the eclipse is viewable in your area, go to:

<http://aa.usno.navy.mil/data/docs/LunarEclipse.htm>

Most everyone has seen a total lunar eclipse at one time or another. They aren't all that rare. But no one has ever experienced such an event from the Moon's surface. What would the experience be like? What would we see in the lunar heavens? How would it transform the appearance of the surrounding moonscape?

For observers on the Moon, what we Earth-dwellers experience as an eclipse of the Moon, will for them, be an eclipse of the Sun, our home star disappearing behind the Earth. So the phenomenon that they would/will experience will bear closer comparison to the one that those fortunate enough to have seen a total solar eclipse on Earth have felt.



Shown: Moon passing thru Shadow Cone (Umbra)

Let's try to visualize and feel the sight and impressions that would-be future Lunan pioneers can anticipate.

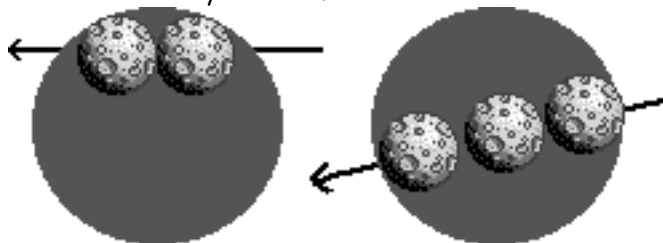
Comparisons

Those of you fortunate enough to have witnessed totality in a total solar eclipse (anything even a tad short of totality counts as zilch - yes, there is that much difference) were probably as little prepared for the overwhelming effect of the experience on oneself as I was, when I saw my first from Minot, North Dakota in February 1978. The sky darkens gradually, suddenly going black, as the Sun disappears and the stars come out, in what should be bright daylight. Where the Sun had been there appears in its place a very black hole in the sky surrounded by a ring of flames, the corona. Meanwhile the air temperature drops some tens of degrees, and an eerie silence falls. For many first time witnesses, the experience is so unexpectedly transfixing that the goal of seeing yet another total eclipse suddenly soars out of nowhere to somewhere near the top

of one's personal life agenda. For me, that quest next led to Bratsk, Siberia in late August, 1981.

Much of the magic of this experience arises out of an unlikely coincidence. The size and distance of the Moon makes its apparent size vary from just smaller to just a bit larger than the apparent size of the Sun. Total solar eclipses occur in the latter case. Because of the close approximation in apparent size, totality is brief, commonly two minutes give or take, with a maximum of seven.

But from the Moon, Earth's apparent diameter is some three and a half times as great as that of the Sun. When the Sun disappears behind the edge of the Earth, it will take quite a bit longer before it peeks out from the other side. Totality on the Moon can last some three hours.



Short Totality

Moon just inside Umbra

Longer Totality

through center of Umbra

For us on Earth, during totality, the Sun's flaming corona can be seen surrounding the black hole in the sky that is the Earth. From the Moon, the Sun's corona will also be eclipsed for most of totality. However, the black Earth will sprout its own "coronalet" as sunlight beaming down upon the hemisphere of Earth turned away from the Moon, lights up the dust in the atmosphere. This light is refracted into the shadow cone. Portions of the Moon passing closer to the edge of the Umbra will be brighter, those closest to the mid-umbra darker. Clouds and volcanic dust in Earth's atmosphere will also have an effect so the actual appearance, brightness, colors and color variation will change throughout the event and differ from eclipse to eclipse.

Watchers on the Moon will see an unbroken ring of sunsets and sunrises, much less brilliant than the Sun's corona, but also much larger in diameter, and an awesome sight. Stars hidden by the Sun's glare will reappear in the sky. The glow from this 'coronalet' will repaint the Moon's surface in very unmoonlike hues. For the pioneers, it will be a magical time in which they might imagine themselves transported to deep twilight on Mars! The direction and length of shadows will not change from what they would be if the Earth were not blocking the Sun. But the edges of shadows will be much fuzzier, contrasts less sharp. Familiar moonscapes will reveal themselves in this whole new light. For crews, tourists, and settlers on the Moon's nearside, it will be an unforgettable experience. While for them, this will be a "solar" eclipse, the real show will be on the Moon's surface, with the show in the sky just completing the "Landscape." That's in contrast to the experience of solar eclipses on Earth where the main event is in the sky.

For a treatment of the coloration and brightness-darkness of the Moon during Umbra, see "Danjon Scale:"

<http://sunearth.gsfc.nasa.gov/eclipse/OH/Danjon.html>
and for the upcoming eclipse: [//sunearth.gsfc.nasa.gov/eclipse/OH/OH2003.html#LE2003May16T](http://sunearth.gsfc.nasa.gov/eclipse/OH/OH2003.html#LE2003May16T)

Timing and Frequency

How often do these events occur? The Moon's orbit around Earth is tipped some 5° to Earth's orbit around the Sun, so the Moon spends most of the time either above or below the plane of Earth's orbit and does not pass through Earth's shadow every orbit. There can be as many as three eclipses a year, as few as zero. Only a third are total. While one seldom sees either lunar or solar eclipses noted on calendars -(just the phases of the Moon), "umbra" dates are likely to be noted on Lunan calendars.

Where on the Moon Eclipses will be visible

The Umbra Experience is only visible on the Earth-facing side of the Moon. That means that the Sky Show of black Earth outlined by the ruddy sunrise-sunset ring of dust-refracted sunlight will be high overhead in the central areas of nearside (the "crooknecks") and at more comfortable elevations above the horizon nearer the limbs (in the "postcardlands"). Some events may be visible in the limb regions, others not, depending on the angle of libration (variance from facing Earth dead-on) at the time.

Both the proposed Angus Bay and North Junction sites will offer comfortable viewing, with Earth some 20-30° above the horizons, with shadows of mid-range length. In contrast, at a site near the center of nearside, not only would the sky show be directly overhead (zenith), but there would be no shadows, it being a high "un-noon" situation. Tourists coming from Earth to experience the umbra will head to areas closer to, or in the limb region.

Umbra will occur early in dayspan for areas east of the Earth-facing meridian, at mid-dayspan along that meridian, and later in dayspan for areas to the west.

Impact on Frontier Culture

The Moon is a world of gray shades, overwhelmingly so. Indeed, Lunans will be challenged to infuse their homes and settlement areas with color to make up for the sensory deprivation that greets them out on the surface. To be able to view familiar out-vac surroundings through the filter of sunlight refracted through Earth's dusty sunrises and sunsets will bring periodic relief and delight. Umbra will also provide the best viewing of the many clusters of city lights on Earth's night side, framed in the sunrise-sunset ring.

The hours-long event will be occasion enough to let kids out of school, even workers. Umbra could even become a holiday of sorts. For these pioneers, who will have given up much that we take for granted, who can begrudge them this periodic pleasure. Add to that, that each Umbra will be different, and the same event will be experienced differently in various places on the Moon. <MMM>



Agriculture on the Moon: “Seasonal Crops” Year Around

by Peter Kokh

Spring is here in the Northern Hemisphere, and at least in the hearts of some of us with an available plot of land, that leads to garden planning or garden-dreaming at any rate: vegetable gardens, flower beds, landscaping, etc. So let's transpose ourselves to Luna City for a moment.

On the Moon there are no seasons, just the eternal cycling of dayspan and nightspan every 29.53 Earth days. Inside lunar settlements, shielded by layers of regolith against extremes of hot and cold, cosmic rays, solar flares, and micrometeorite rain, we will be able to pick the mini-biosphere climate we want. Perhaps we'll decide to allow the temperatures in common "middoor" spaces of settlement streets and parks to vary naturally from a late dayspan high in the mid 80's (31°C +/-) to a late nightspan low in the low 50's (12°C +/-). Of course, we could keep it warmer, cooler, or allow an even greater fluctuation.

Our crops can be grown in separate areas with their own temperature and humidity controls. It'll be easy to grow subtropical and tropical plants. But what about plants that seem to require a winter reset, a chilling period, or even a hard frost before they can sprout afresh? Many of us are very attached to such crops, among them most of the berries and other common fruits. We may have to grow them under conditions that provide a simulated winter. Not being tied down to the annual cycles of the solar year, we would want to have as many harvests per year as we could cycle through the necessary stages.

We could experiment, but experimenting takes money. On Earth, experiments get done when the economic circumstances make the potential payoff attractive. And this seems to have been happening on its own the past few years with respect to Raspberry production. The happy result is that we now have the know-how to produce these delicious berries year around in climate-controlled greenhouses: a perfect model for lunar settlement agriculture.

Raspberries will not begin to grow even in warm temperatures until their specific amount of chilling required to terminate rest is satisfied. The chilling required to break rest varies between varieties / growing conditions and is between 600 hrs (25 days) and 1500 hours (63 days) at temperatures below 40 °C (39.2 °F) for maximum bud break and growth. Bud growth will occur when plants are exposed to favorable temperatures after this chilling.[1]

The Economics of Winter Raspberry Greenhouse Crops

Consumers demand a year-round supply of high quality raspberries, as is evidenced by their willingness to pay high prices for fruit imported from Chile and elsewhere during the winter months. Happily, in northern raspberry growing areas such as Washington, Oregon, British Columbia, New York, Ontario, greenhouses are empty during the winter (greenhouse production of edible products has been limited primarily to tomatoes, cucumbers, peppers and lettuce.) Using this available capacity for raspberry production is ideal because only moderate energy inputs are needed, and production is possible under low light and under relatively cool temperatures. Two more plus factors are the commercial availability of bumblebees hives for pollination and the ready availability of the most successful cultivars.

Results to date have been good. Compared to field production, greenhouse-produced berries are larger, firmer, and much less prone to fruit rot. Fruit tends to be slightly less sweet and more acid in the greenhouse, but well within the limits of acceptability. [2] Further, it is proving possible to piggyback other crops on this production: Strawberry plants can share space with the successive raspberry crops, the strawberries in overhead troughs and the raspberries in pots on the ground. [3] Given this happy congress of conditions, it is no surprise that much experimentation has been going on in recent years [4].

Can this success be repeated for other "seasonal" crops? Future Lunans have a stake! Serious greenhouse gardeners can experiment with other fruits and berries (and vegetables, if any) that need a chill reset before the next growing cycle. We can also experiment to see which varieties do better in hydroponic, which in geoponic setups. what's next - other seasonal crops that need chill resets

Such experiments are incomplete, however. We also need to breed varieties ideal for the dayspan/nightspace lighting regimes in lunar outposts, aiming for two dayspan one nightspace (44 day) and three dayspan 2 nightspace crops.(7) with late nightspace germination okay and early nightspace harvest and bed turnaround

Those without green thumbs but with engineering and/or architectural expertise can support this effort by designing greenhouse rack/conveyor systems to stack the plants compactly in chill mode, spread them out for maximum sun in growth mode, etc. Farming equipment designers and manufacturers are very much part of the green revolution on Earth, and will be on the Moon as well! <MMM>

Footnotes:

[1] <http://foodfarm.wsu.edu/GreenhouseRaspberries.htm>

[2] <http://www.umass.edu/fruitadvisor/fruitnotes/FNarticle65-05.pdf>.

[3] www.annexweb.com/greenhousecanada/story2.html

[4] Growing Raspberries in Greenhouses:

A One Day Workshop, 27 March 2003,

U. of Guelph, Simcoe, Ontario, CA <adale@uoguelph.ca>

THE SEASONS OF LUNA CITY

by Peter Kokh

Just the Facts – The Moon's axial tilt is a negligible 1°. So annual seasonal effects of this tilt in the amount of insolation, solar heating per unit of surface area, is negligible except at the poles themselves. More significant is the annual variation of the Moon's (and Earth's) distance from the Sun. That distance is least ("perihelion") at the beginning of January, and greatest ("aphelion") about July 1st. The extra thermal buildup in the regolith top layer blanket of moondust lags somewhat and is about 3° C (5° F) higher in March than in September. That will mean that much more of a burden on excess heat radiator systems. If the radiators are not up to the extra load, that might mean slightly warmer interior temperatures in settlement open spaces or Middoors for that period. Not quite what we would dignify as a "seasonal difference."

Such a minimal fluctuation should be easy enough to damp out, or temper, with the shorter 29.53 day long sunthly cycling of exterior dayspan and nightspan having a much greater effect on the climate within the settlement biosphere. Middoor (parks, streets, other common spaces outside of residences and offices and work places, but inside the settlement "hull" could be allowed to fluctuate naturally in a tempered sunthly pattern from say the mid-80's °F* towards approaching sunset to the mid-50's °F* towards sunrise two weeks later. This is a design question and something the settlement founders and biosphere engineers can decide before hand, in choosing their "climate."

* F	-4	5	14	23	32	41	50	59	68	77	86	95
104												
C	-20	-15	-10	-5	0	5	10	15	20	25	30	35
40												

Separate settlements may well choose differing upper and lower temperature limits, and may even choose to impose annual or multi-sunth "seasonal" variations of temperature and humidity in order to accommodate vegetation with seasonal fluctuation requirements for germination and fruiting, etc. Differing choices of climate and degrees of seasonality will lead to a distinctive ambiance for each. The resultant differences in flora (and fauna) may help protect against the spread of plant diseases between settlements. It should also help promote intersettlement tourism and trade in distinctive flora and fauna based products.

Seasons & Urban Wildlife - Some insect, birds and mammals have mating and birth or hatching cycles that are closely coupled to seasonal differences in temperature, lighting conditions, etc. It will be difficult to successfully transplant populations of such species to lunar settlements without reproducing or simulating such climactic clues and sequences. While some species are relatively omnivorous, others demand particular plant species for food, or even

the presence of particular animal prey.

We will do well to look for animal species that are not only non-parasitic on the vegetation species we want to support but which are not that particular in their eating habits, and not that restricted in their life cycles by particular climactic and seasonal conditions. In other words, we will want to pick insects (bees, butterflies, etc.), birds, pond and stream fish, and small mammals that adapt well to a great variety of conditions.

Some we will want to complete our ecosystems, others for food production or agricultural needs, others for just plain enjoyment (butterflies, hummingbirds, song birds, goldfish and koi, even squirrels.) One man's pest is another's delight. Which will do best may depend on the type of climate and seasonal variation that is being reproduced or simulated. Thus the "wildlife" in one settlement may well differ from that in another.

Some transplants may be successful from the very start. Others may require a bit of trial and error experimentation.

The basic challenge, however, remains: how do we harmonize any seasonal rhythms desired plants and animals may have with the sunthly climate swings of alternating two week long dayspans and nightspans, sure to be reflected in habitat and farm area temperatures and light levels. We can wait until we get there, or take advantage of whatever opportunities may come our way to experiment here and now with terrestrial market needs subsidizing the cost of the experiments, as in the Raspberry Production story reported above. The lessons learned in that case are a perfect example of serendipity. Now that we see what can happen fortuitously, it behooves us to be on the lookout for more such opportunities for dual purpose research.

We need an experimental agriculture team that would be on the lookout for just such opportunities. <MMM>

Relevant Reading from MMM back Issues

- # 2 FEB '87 "Moon Garden"
- # 8 SEP '87 "Parkway" & "Animal Life"
both republished in MMM Classic #1
- # 43 MAR '91, pp 4-5, "Dayspan", "Nightspan", "Sunth"
- # 50 NOV '91, p 8, "Trees on the Space Frontier"
both republished in MMM Classic #5
- # 85 MAY '95, p 7, "Rural Luna Cont: Farm Tarns"
republished in MMM Classic #9
- #109 OCT '97, pp 3-11, "Luna City Streets"
republished in MMM Classic #11
- #148 SEP '01, pp 3-11, "Earthpatch: Anchoring Lunan & Martian Homesteads"
- #149 OCT '01, pp 5-8, "Homestead Gardens & Early Cottage Industry"
both republished in MMM Classic #15

Online Reading - The LUNAX Experiments

<http://www.lunar-reclamation.org/lunax/>

LUNA CITY YELLOW PAGES

To all of our MMM Readers

From MMM Editor, Peter Kokh

Many of you are relatively new to MMM, although there are a number who have been with us for all our sixteen plus years. In that span we have covered a lot of topics, many of them illustrating the possibilities for life on the lunar frontier. There are quite a few good past articles still worth reading, and unfortunately, for a number of reasons (all coming down to a lack of time on my part) only some of them are online. Readers with online access are encouraged to browse at:

<http://www.asi.org/mmm>

It occurred to me that I could reprint some of these articles, But then I decided on another way to recap many of the ideas and possibilities covered in these essays: publishing a column, a page, or pair of pages of the

Luna City Yellow Pages

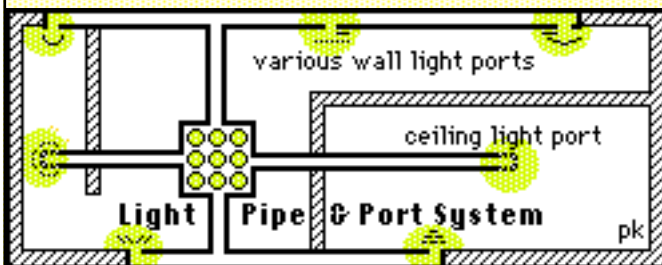
in each future issue. So we start this issue. Enjoy the ride, or should I say, the "tour?" <PK/MMM

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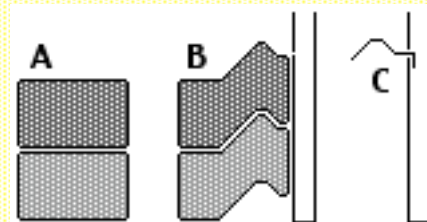
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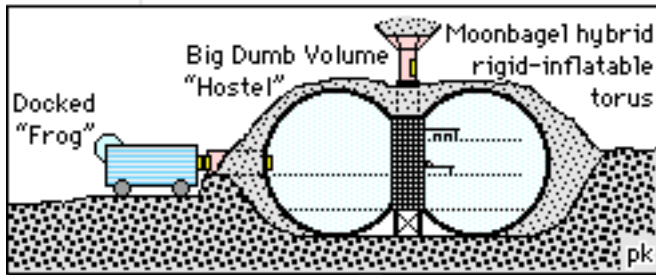
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Brainstorming the Frog & Hostel Gambit

Below, in this issue, J. Craig Beasley, examines the details of Peter Kokh's proposal for a low threshold starter lunar base [ISDC 1991 Paper & MMM #153]. What things have to be considered to make the "Frog & Hostel" approach work to best advantage? Others are encouraged to help take the devil out of the details in advancing this alternative "Reference Mission" architecture.

Settlement Garden Tours: A Favorite Frontier Pastime

by Peter Kokh

Why Settlement Gardens will be Tour-worthy

Without the multi-shade greens of the garden, without the bright colors of flowers and fruit, the gray monochrome color schemes enforced by available building materials will become dreadfully dreary. Public and private gardens will provide an ever changing feast of eye candy.

More importantly, lunar settlement will always be to some degree "provisional." Talk of returning to the Moon, or settling Mars, "for good" may be a statement of unanimous deep commitment, but without a planetary biosphere that could live on without our constant tweaking, our continued existence will always be "tentative" and dependent on our collective economic success and environmental "good behavior." In each settlement, all habitable spaces and structures will share a pressurized "safe house" and a shared minbiosphere nourished within it. That human-installed biosphere will always be at risk, never be more than several months away from becoming a "ghost town." Lunans will know that, and take it in stride, much as people survive day to day in areas where death by senseless terrorism is an ever present possibility.

Given the native barrenness and sterility of the Moon, nothing will be quite so comforting to most pioneers as vegetation and lots of it - greenery and flowers - and healthy crops of grains, fruits, vegetables, herbs and spices. At first, the number of successfully transplanted species will be small. The pioneers will be especially encouraged, heartened, and delighted with the establishment of each new species, whether it means a welcome addition to

food menus, a source of natural dyestuffs, new fibers, medicinals, or just purely ornamental. The truth of the matter is that increasing biodiversity within the settlement biosphere will mean increasing strength and vigor, increasing resistance to environmental catastrophe, and progress towards a true biospheric "flywheel." But we are not talking just about what is needed to keep our bodies alive, but also about *what is needed to keep spirits alive* -- and productive.

Garden tours of noteworthy green spots, whether in settlement farm areas, parks, streetside landscapes, or private homesteads should be a very popular and frequently indulged pastime. From year to year there will be more to see: new food crops, new landscape plants, new flowers. These tours will work to instill a real sense of biospheric progress in both diversity and security. Pioneers will notice that more and more of "Gaia" has made the move outward with them. They will feel less and less biologically isolated. That must also be making economic progress, of course.

Garden Tourists

Who will go on such tours? Certainly the local inhabitants! But also visitors from any other lunar settlements and outposts that may be established over time. For, as the Moon has no "climate" other than the 29.5 day long sunthly cycling of dayspan and nightspan, the various settlements and outposts may each choose differing types of vegetation and crops. These differences will help fuel intersettlement and interoutpost tourism -- and rivalries!

Some Earth tourists may want to do the garden circuits, but for many of them, there will be little to see that holds a candle to what they take for granted on Earth -- unless Lunans succeed in growing flower "forests" of especially tall plants in light gravity, a yet to be proven prediction of Arthur C. Clarke. No, the real reasons for garden tours will be to encourage the spirits and morale of the pioneer settlers, and to spur healthy competition and spin-off garden-based cottage industries and enterprises.

What's to see on agricultural / horticultural tours?

What's to see will change constantly. The Local Gardens Online magazine will post farm areas, streetside landscapes and plantings, and open house private gardens available for touring along with hours and other particulars. Download the self-guiding tour lists and hit the byways.

There will be rows and rows of crops in the agriculture areas. As the seasons can be separately controlled in the various farm areas, there may always be something in bloom, something ready to harvest or in the process of harvest. The season you are in the mood to experience may be but a walk away. Many agricultural areas may include picnic facilities and mini parks in their midst, respite places from the hectic pace of life and frontier stress.

Along settlement thoroughfares and byways, every plantable square foot put to good use, there will be beautiful landscapes and flower beds in every state of season. Even the lower part of curved cylindrical walkway module

walls can be used for diversified terraced plantings without taking up flat space needed for walking. Some of these landscapes and gardens will be planted and cared for by garden clubs, rather than by the settlement municipality.

Water for garden use, even for ponds, fountains, and waterfalls in garden settings will likely be waste water in advanced stage of treatment. We can stretch limited water reserves much further if put it to work at every stage of the recycling loop. Both public and private gardens on tour will commonly have water features. Some will be unique enough to merit special notice in online tour guides.

Homesteads will be interconnected within a larger biospheric maze, each opening via a securable pressure door onto a pressurized "street" on the analogy of our terrestrial residential blocks. If these streets are sunlit at intervals, then these frontages are also opportunities for private gardens in public view, testaments of civic pride as well as personal pride of place.

On the Moon or Mars where surfaced "lots" are barren and lifeless, the "front yard" and "garden" has to be *interiorized*, located in the "reclaimed" space within the pressure hull complex. It is likely that many, if not most (or all) modular homesteads will include indirectly sunlit interior garden spaces. Private homestead gardens bring many advantages: interior air quality; point source treatment of toilet wastes; supplemental herbs, fruit, and vegetables; garden stuffs for cottage industry income; the delight of greenery, flowers and garden scents; pools of sunlight; the reassuring contrast to sterile moonscapes out the window; and more -- in sum, a psychological security blanket.

Not all private gardens will be tour worthy. Even the best of them will merit a visit only at certain times. Nonetheless, home garden tours on the Moon and Mars may be every bit as popular as they are in our own cities and suburbs. Here we will find more varieties of plants, greater diversity of design, and something special: garden products for sale, some not be available anywhere else: jams, jellies, pickle relish, herbs & spices; wood jewelry, home crafted paper art and products, etc. The list of potential garden-derived cottage industry products is endless. Times, locations, descriptions, specialties can all be advertised online in a common Garden Tour watering hole website.

Adding to the treats of greenery, flowers, and garden design, will be the sights, sounds, and smells of water features. Delighting many will be the sights and sounds of the vegetation-hosted urban wildlife hosted: song birds, hummingbirds, butterflies, bees, fish, and other creatures.

We can expect many stands selling garden produce and products: fruit and berries and jams, jellies, and pies; vegetables and other salad stuffs and salads; herbs and spices and dyestuffs; specialties not available from settlement farms such as coffee, tee, hot peppers, and more; gourds, dried flowers, home made craft papers, baskets,

mats, and wreaths; seeds, shoots, sprouts, bulbs; how to books, garden tools and apparatus; home made fertilizers and other soil amendments. All of these things, the result of a healthy homestead garden-based cottage industry.

Garden tour traffic will be inviting to other entrepreneurs, artists and craftsmen as well, and there will be home made glassware and ceramics and other non garden-based creations for sale as well. And music, both canned and live! Add food and drink in great variety. Truly, there will be no better way to take the pulse of an increasingly thriving settlement than by making in the garden rounds.

In sum, on the frontier, *interiorizing* the biosphere will become not only public practice, but also *second nature* for each pioneer. Children will grow up with *the biosphere instinct* and be green-conscious, freshwater conscious, fresh air-conscious. Settlements cannot survive long term without a culture of *greening wherever possible*. While not all of us have *green thumbs*, most children can learn how to care for plants, and learn to enjoy doing so. <MMM>

Trees in Lunar Settlements

In 1990, a student working on the NASA grant Genesis CAD [computer assisted drafting] Project for Lunar Base & Habitat Design at UW-Milwaukee's Dept. of Urban Planning and Architecture, produced an interesting plan in which his base design was capped by a dome "to provide a place for trees". A NASA auditor excitedly protested that there was no way we could afford to waste space in such fashion. The student, unabashed, replied that if there were no trees, it would not be a human place, a place fit for human habitation; he stuck with his design.

This little anecdote illustrates a real dilemma. Even if the costs of space transportation fall, spaciousness will still be at a premium until we begin to build expansion shelter from local building materials. But even with locally produced housing, pressurized areas will still tend to be close-ceilinged, without tree-scale headroom; for the Nitrogen needed as a buffer gas to pressurize extra volume may well be a costly import.

Yet the student's observation is quite on target. Without trees, we'll have only a caricature of a human place, despite the fact that in some desert and plains areas, people *do now* live without them. Trees are essential to the functioning of Biosphere I (Earth!) Second to oceanic algae and phyto-plankton, Earth's forests make the greatest contribution to the sweet oxygen necessary to all higher life forms, single cell on up.

What place will trees have in the mini-biospheres of the Moon and Mars? Their ornamental use in landscaping will be a minor consideration. Yet, for frontier agriculture, trees would add greatly to the variety of fruit, syrups, pulp, fiber, artstuffs etc. - needs that are less easily satisfied by smaller plants or bushes. Happily, tree "dwarfing" by

nursery breeders serving home gardeners has made much progress. Settlement orchards may feature short but fruit-laden apple, orange, pear, peach, and cherry trees, etc.

"Arboriculture" is one radical proposal to grow nothing but ultra-fast growing trees on lunar or space settlement farms, harvest them for pulp to feed vat-cultures of microorganisms to transform this fodder into synthetic foods of every imaginable taste and texture. This pseudo "Solyent Green" may well be the most efficient way to do farming on the space frontier.

Bonsai miniature trees can provide ambiance for early pioneers. The Japanese have long cultivated the art of dwarfing trees by controlled pruning and fertilization, grown them in small pots into caricatures of older, bigger trees. Evergreens, leafy deciduous trees, vine and fruit-bearing varieties are all successfully miniaturized. Waist-high setback platforms in passageways can be lined with Bonsai forests. <MMM>

Loading the Ox-Cart: The "Frog" & "Hostel" Refined

(c)2003 by J. Craig Beasley < bginstitute@ev1.net >
<http://members.tripod.com/bginstitute/index.htm>

BACKGROUND: The original paper, **"The Lunar Hostel: An Alternate Concept for First Beachhead and Secondary Outposts © 1991"** was presented at ISDC 1991 in San Antonio, and printed in its entirety in the Proceedings of that conference. The paper is online in two parts with the original illustrations:

http://www.lunar-reclamation.org/hostels_paper1.htm
http://www.lunar-reclamation.org/hostels_paper2.htm

In MMM #153 {March 2002}, Peter Kokh made a compelling case for a Frog & Hostel Artemis Reference Mission. In a nutshell, this is a mission scenario in which:

- A separate living and working module is established on the Moon without much, if any, independent operational capability. This would be the HOSTEL.
- A crewed spacecraft, upon landing on the Moon, taxis to the Hostel and, docked with it, provides for the Hostel's lack of independent capability. This craft will later undock, taxi back to the landing site, and serve as the Earth return vehicle. This would be the FROG.*

[* This term denotes the vehicle's "amphibious" nature, able to operate in space and on the Moon's surface. PK]

Employing the Frog & Hostel system should provide an early ability to "overnight" on the Moon. It is truly an intriguing idea to explore. In that exploration, there is one concept that Peter mentioned that could be in question:

"It will probably take several missions to build up this capacity to overnight." - Peter Kokh

The quote above brings some questions with;

- Are sure it will take several?
- How do we quantify "several"?

Certainly, a series of missions will be required to establish a self-contained long-duration facility, but it may not be all that difficult to build up an "overnighter" capacity to the system. It is a matter of how the hardware is designed, and what technology is available. The speed with which we establish an overnight beachhead rests on how much of the necessary supplies and facilities we can deliver per launch. If there is excess launch mass to be had, we would be foolish not to take advantage of the situation. A full assessment of such issues seems to be in order, so let's take a look at that.

"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 the first mission." - P. Kokh

This is completely true, and is the basis on which the Frog & Hostel concept exists. Obviously, launch mass plays a major role in how all mission systems are devised. This leaves us with the inevitable need to decide what functions we include on the Hostel side of the equation, and what is part of the Frog side. The trick in either case is to optimize both halves of the Frog & Hostel system.

This optimization would be guided by the following:

1. What are our bare minimum hardware and consumables for survival at any point of the mission?
2. What is the mass of the minimum hardware and consumables?
3. What are high-priority, but non-survival class items?
4. What is the mass of the non-survival class items?
5. What is our minimum lifting capacity available per launch?
6. What mitigating factors demand that certain systems reside in either one or the other half of the Frog-Hostel system?

Given the above, here's one way to proceed on creating a baseline designing the Frog & Hostel system:

1. Designate all mandatory items for the Frog.
2. Calculate maximum weight of the survival-equipped Frog.
3. Subtract the mass from Step 2 from the minimum per-launch lifting capacity.
4. Designate all mandatory items for the Hostel.
5. Calculate the maximum weight of the survival-equipped Hostel.
6. Subtract the mass from Step 5 from the minimum per-launch lifting capacity.
7. From a list of non-survival items, sorted by mass, application, and relative importance, allocate as much of these non-survival items as possible in the manifest of the Hostel.
8. From the remainder of the list of non-survival items, allocate as much as possible to the Frog.

The main goal of the above baseline is to ensure

that the Hostel carries as much hardware as possible to the Moon, on a one-way trip. Starting with an emphasis on survivability, we've ensured that each system, in their independent roles, will provide for the needs of the occupants. After survivability is addressed, then the system provides at least some excess capability to send desirable items to the Moon to stay. This will minimize the time and number of mission launches required to make a useful outpost. Indeed, this will compress the time reach an "overnighter" capacity, which is a major goal.

Of course, this is a very simplistic overview of how to produce the Frog & Hostel complex, but it should provide a framework to build upon. The next task would be to populate the optimization and baselining steps with more detailed questions to answer.

Below are my assumptions, which are up to revision. Revision by any reader is encouraged - I want the experts to speak up. We can develop the detailed architecture of the Frog & Hostel complex together.

Optimization:

1. What are our bare minimum hardware and consumables for survival at any point of the mission?
 - Structure and Pressure Shell for the Spacecraft.
 - Life Support Systems, including air and water for three crew to and from the Moon.
 - Reconstituted foodstuffs for 10 Days Transit
 - Fuel / oxidizer for propulsion / maneuvering thrusters.
 - Bare minimum power generation capability for Frog Guidance-Navigation-Control (GNC), in the form of solar cells and/or fuel cells. The latter should be the preferred source, since it can typically provide more copious and predictable amounts of electricity than solar cells. Fuel cells are admittedly more difficult to produce, but the technology can be obtained nearly off-the-shelf.
 - EVA supplies for in-transit contingency
2. What is the mass of minimum hardware / consumables?
 - This must be determined in work outside of this article. Experts are encouraged to fill in data holes that exist.
3. What are high-priority, but non-survival class items?
 - Foodstuffs - Fresh
 - Excess Fuel for discretionary maneuvers
 - Excess Power capacity
4. What is the mass of the non-survival class items?
 - This will need to be determined in work outside of this article, as well. Once again, experts are encouraged to fill in the data gaps.
5. What is our minimum lifting capacity available per launch?
 - This requires a survey of what launchers are available, or are projected to be available at the date of launch.
6. What mitigating factors demand that certain systems reside in either one or the other half of the Frog-Hostel system?

Another issue for the experts - Baselining:

1. Designate all mandatory items for the Frog.
 - Structure and Pressure Shell for the Frog.
 - Life Support for In-transit Duration
 - Foodstuffs, shelf-stable
 - 10 Days Transit
 - Fuel / oxidizer for propulsion / maneuvering thrusters
 - Power generation capability for Frog Guidance-Navigation-Control (GNC), in the form of solar cells and/or fuel cells. The latter should be the preferred source
 - Power generation capability for Lunar Launch Standby
 - EVA supplies for in-transit operations.
2. Calculate maximum weight of the survival-equipped Frog.
 - The maximum mass will have to be developed ahead of time, via expert analysis.
3. Subtract the mass from Step 2 from the minimum per-launch lifting capacity.
 - This will give a margin to work with for Step 8.
4. Designate all mandatory items for the Hostel.
 - Structure and Pressure Shell for the Hostel.
 - Life Support for 14 days (Half-Sunth)
 - Foodstuffs, shelf-stable.
- 14 Days (Half-Sunth)
 - Power generation capability for Hostel electronic systems, in the form of solar cells and/or fuel cells. The latter should be the preferred source.
 - Power generation capability for Lunar Launch Standby.
 - EVA supplies for surface operations, 8 hrs/day for 14 days: 112 hrs of capability
5. Calculate maximum weight of survival-equipped Hostel.
 - The maximum mass will have to be developed ahead of time, via expert analysis. Factored into this will be the mass of the Hostel structure and pressure shell, which should be relatively simple to determine from SpaceHab module mass numbers.
6. Subtract the mass from Step 5 from the minimum per-launch lifting capacity.
 - This will give a margin to work with for Step 7.
7. From a list of non-survival items, sorted by mass, application, and relative importance, allocate as much of these non-survival items as possible in the manifest of the Hostel.
 - This task will take considerable planning, and will vary to accommodate each mission profile.
8. From the remainder of the list of non-survival items, allocate as much as possible to the Frog.

The outline above is the barest of skeletons upon which to build a spacecraft complex. All these issues will require more focused attention if we want to bring the ideas into realization, but it seemed important to start somewhere. Begin at the beginning - the details will work out over time. NEXT MONTH - The Details

LUNA CITY YELLOW PAGES

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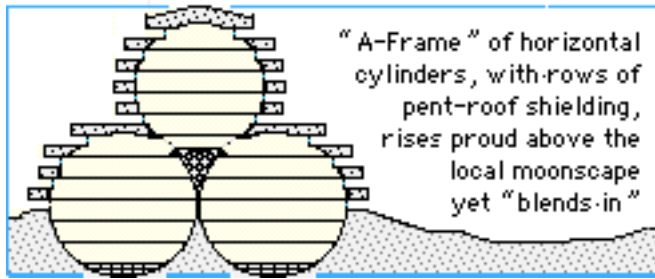
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Building with Pride? Or with Respect?

Not all the structures we build on the Moon will be burrowed into its surface, showing only telltale "mole-mounds" of regolith shielding blankets above. Should our above surface presence proudly assert our ability to make ourselves at home? Or should our architecture pay its respects to our adopted world, and seek to "blend in"?

Perhaps we can do both. For more, see *Below*.

A Breakout "Cycling Strategy" For Space Commercial Development, Lunar and Mars Settlement

by Dave Dunlop < dunlop712@yahoo.com >

My reaction to Dave Dietzler's interesting article entitled "The Interlunar Cycling Station: Traveling First Class," is that it contains the seeds of a much broader strategy for opening the space frontier. The need for a major change of strategy could not be better timed than in the aftermath of the loss of Columbia and the renewed debate on the future access to space for the U.S.

The destiny of the International Space Station without the shuttle is a great unexpected hitch in business as usual for NASA. It seems likely that after the appropriate commission reports there will be a judgment that if the insulation problem on the external tank is fixed we can resume use of the Shuttle. To continue with the Shuttle is a political high wire act. Another seventeen years of operation without a catastrophic accident might provide the time for another system to be developed. However, another major accident in the near term would be politically devastating, undercutting the credibility of NASA and make raising political support for major investments very difficult.

Both businesses as usual for the Shuttle and for the International Space Station are at stake. It would seem to be a matter of prudent management to increase the manned options available to support the ISS. The "near term" options may be in advanced development as the Air Force funded X-41 and X-42 "black" projects originally solicited in 1998 as discussed in the May issue of *Popular Mechanics* magazine.

Heavy lift capacity might be developed by Shuttle-derived vehicles with greater cargo capacity than the current shuttle. Such vehicles have long been proposed* and would not require propulsion systems development but a modified structure capable of lofting a large faring on top of the external tank.

* Examples: Shuttle-C proposal and Zubrin's *Ares*

The split of manned access, with fast turnaround for frequent flights, from the heavy lift option must be designed in anticipation of the next big thing(s).

However, there is no consensus about what is the next big thing. What is clear is that manned safety and reliability and frequency must be increased while costs are reduced. It is also clear that flexibility and applicability to a variety of mission options is also needed in planning for the post-Shuttle space transportation system [STS]. Buzz Aldrin's Starcraft fly-back booster based launch system might provide both the above mentioned frequency, reliability, safety, and flexibility as well as lower costs.

The "Next Big Thing" options include:

1. Full development and manning of the ISS with broader participation including China and India. Manned vehicles and unmanned cargo options might also result from the political aspirations of China.
2. A Next Generation Rotating Ring station designed as a major research facility, Earth observation platform, destination for limited space tourism, and staging area for lunar and commercial power projects should be considered. Utilization of standard external tank modules would create a market for a large number of such ETs. This station would be built in equatorial orbit.
3. A permanent return to the Moon.
4. Prototype solar power satellites at Lagrange points.
5. Refueling capacity and fuel storage will be needed for a permanent return to the Moon and/or commercial solar power satellite construction. Such tank farms may be needed in LEO / Lagrange sites to support development.
6. A rotating ring Next Generation Space Station at L2.
7. Construction of the Interlunar Cycling Station.
8. Development of R&D equipment on the Lunar surface for the Lunar Power System proposed by David Criswell.
9. A multi-ring rotating space station for Mars orbit.
10. A rotating ring cycling vehicle for Mars Transit.
11. Exploration and settlement of Mars.

The Shuttle External Tank as Key to all these scenarios

Over the next 20-30 years, this list of projects would create a high volume market demand for external tank type units used for habitation, research, and industrial production over a long time for a variety of manned missions. This approach should lower the cost per unit considerably. These developments would be supported by an expanding global economy and a growing number of nations involved in space. These expanded sponsors would target

development of space power as a major energy resource for the growth of Earth's economy.

This broad long term view of design options is the development scenario that promises to move from a government subsidized space program to a program that can produce major revenue with a high rate of return on commercial power investment.

The development of rotating stations and transit structures is also a means of addressing the problem of human adaptation to the zero-gravity environment of space. This strategy seems also to address the dead end of zero-gravity space station facilities.

The replication of these structures at various stages of development would begin the routine industrialization and expansion of access to LEO and beyond, for a variety of goals by an expanding number of investors and participants.

Both separation of manned access from shuttle-derived launch systems and the utilization of external tank scale modules with large volume for multiple purposes are needed to lower costs and increase flexibility for a growing number of nations with a wide variety of space goals.

Our transportation architecture must account for all these options if we are to have a robust expansion that rides a growing global economy to a reliance on space-based resources as a major vehicle for the expansion and sustenance of that economy. Make no small plans. <DAD>

Total Lunar Eclipse Postscript

PHOTO: www.third-wave.com/dembow/forward_002.htm

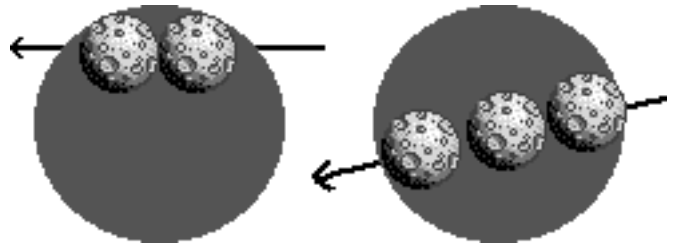
Remarks (not photo) by Peter Kokh

I *did* get a chance to view the recent total eclipse on the evening of May 15th, but sans binoculars or scope, unfortunately! Taking in the experience, a number of things occurred to me not mentioned (or thought of) in my previous article in MMM #164 APR 2003, [pp. 18-19 above]

Direction and Speed of Advancing Umbra Terminator - the *regular* terminator of sunrises & sunsets advances westward on the Moon (as on Earth) at 9.5 mph = 15.5 kph (cf. a 6.3 min. mile or 3.9 min. kilometer run). The Umbra terminator comes out of the west, moving eastward at speeds in excess of 3,700 mph = 6,000 kph! An enormous difference!

Umbra-clad moonscapes - where one is on the Moon will make quite a difference. The relative brightness of the brighter highlands and darker maria (lava plains or "seas") will be much the same. The reddish umbra light may make some areas stand out. Shadows will be in reduced contrast with the umbra-lit areas and have softened edges (owing to the greater diameter of Earth's sunrise-sunset ring than the angular size of the sun's disk), but in the same direction.

During a short totality (left, below) such as the recent May 15th-16th eclipse, portions of the Moon nearest the edge of the umbra shadow remained relatively bright,



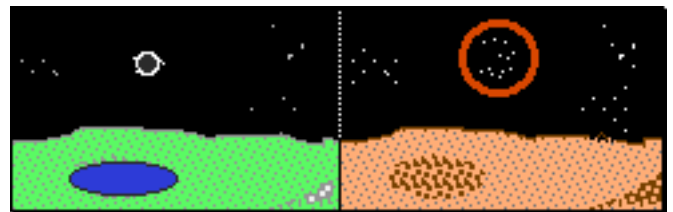
where as portions deeper within the umbra were considerably darker. For pioneers, the brightness or darkness of the eclipse "twilight" and of surrounding moonscapes will depend on one's position on nearside relative to the umbra center.

Popular vantage points - The spectacle will be more comfortably viewed the further one is from the center of nearside (the closer to the horizon Earth sits in the lunar "sky.") Vantage points that include both mare and highland terrain in the foreground will be more interesting. "Experts" and Umbra devotees may seek out special vantage points.

Visiting Tourists - People will come to the Moon from Earth, even from Mars, to experience the brief spectacle. Because of demand, prices for Lunar Eclipse Excursions may be higher. An eclipse experience would highlight a visit

The Spectacle of Earth's city lights - In MMM # 69 OCT '93, p 8-9, "7 Wonders of the Moon," [MMM C #10] I listed my personal picks which included the Nearside Spectacle of Earth in the heavens. But I was thinking of viewing Earth under normal phase conditions - the Bright Blue Marble. I think that the Nearside Umbra experience (*far the best* to view Earth's city lights) should be added to the list, expanding it to eight, or supplanting the Straight Wall. The others: (Nearside) Copernicus (or other major crater), Alpine Valley, Lavatubes, (Farside) Tsiolkovsky, Milky Way splendor in the heavens. <MMM>

Total Solar Eclipses on Earth vs. on Moon



During a total solar eclipse seen from Earth, [left] a (Moon-sized) "black hole" shields the disk of the Sun, but the Sun's corona peeks out brightly, prominences clearly visible. The brighter stars and planets are visible in the sky.

During a total eclipse of the Sun as seen from the Moon [right, above], a much larger (3 2/3 as wide, covering 13+ times as much sky) Earth-sized black hole obscures the Sun *and its corona*. This black globe is clearly speckled with the night lights of Earth's urban constellations, no solar glare fogging their visibility. Forest fires, oil field burn off flames, and scattered lightning flashes will also be visible. Meanwhile, as Earth's mini-corona, its sunrise-sunset ring, is much dimmer than the solar corona, Lunan observers will see many more stars shining more brightly.

Board Games for Early Lunans: Mancala or Oware, Anyone?

by Peter Kokh

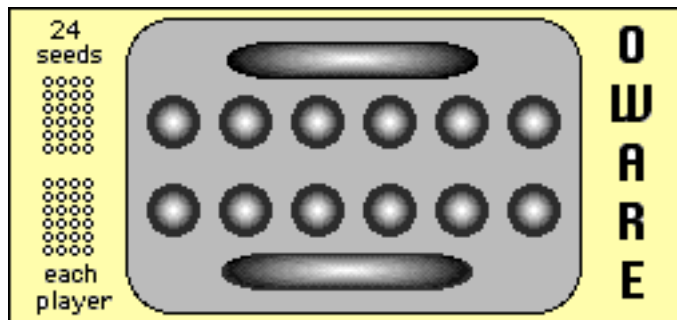
Most would-be Lunan Pioneers probably take for granted that they will have access to most anything they want from Old Earth. Perhaps. Perhaps not. It seems far more likely that the do-or-die struggle to ramp up exports and production for domestic consumption to the point where enough credit is earned to pay for importing those items of necessity that cannot yet be produced on the Moon. Production for domestic consumption and production for export will go opportunistically hand in hand.

Another do-or-die struggle will be to preserve precious volatile elements, hydrogen, carbon, and nitrogen, for use in the biosphere/food production cycles as far as possible, withdrawing these elements from that "bank" on a case justified basis. Fiber for clothing, byproducts to be turned into recyclable children's *art du jour* another.

Game boards wouldn't seem to be a must-have item either imported, or made from biomass bank withdrawals. Not if we can find substitutes. A computer screen can host just about any game board, even if it isn't on-a-table flat or shared by both players. But traditionally printed cardboard games of Monopoly, Sorry, Scrabble, and a myriad of other board games and their 3D game pieces are not likely to show up in frontier stores, or be importable at affordable prices, with or without stiff luxury taxes.

An Ancient African Game to the Rescue

A game played in Africa for thousands of years, under many names, could be a popular, frontier produced substitute, offering many hours of pleasure for all ages, at all skill levels. Ancient Egyptians called it **Mancala**, and to many of today's Africans it is **Oware**, or simply "Pits and Stones." This game is ranked "among the world's best."



Recently, I purchased a hand-crafted Oware set, carved out of wood from some African tree, and found a willing partner. It took less than two games to start experimenting with "strategies" and it was quickly obvious that here was a game, seemingly so simple, that delivered great brain exercise and thrills.

How so? First, the board is carved to contain two rows of six pits, one for each player, plus a pair of special pits for captured pieces. While commonly made of wood,

this is a simple game board that could easily be made of materials available in the early lunar frontier. ceramic by frontier potters or, or glass, or cast basalt. There is no "printing" involved, *only shape*.

Second the game pieces consist of 48 "seeds." nuts, marbles, teeth, pebbles or stones. Anything will do, and these do not need to be individualized. Each piece is playable in turn by each player, so 2-color differentiation is neither needed nor desired. All the seeds can be identical., exactly or crudely. Think of roughly same size lunar stones, raw glass marbles or beads, metal balls.

The Game - The game starts with four seeds in each pit. The first player takes all the seeds in any of his pits and sows them one by one in four pits to the right counter-clockwise, on his side, his opponents side, or both as the location of the opening pit determines. The opponent does the same, again picking as starting pit. You may now have two empty pits, and some pits with more than 4 seeds. The idea is to sow the last seed of your play in an opponent's pit with only one or two seeds, in which case you capture both his, and your own landing seed. And the capture continues clockwise if the second last pit you land on also contains one or two pieces. The idea is to capture 25 seeds (remove them from play to your capture pit) in which case you win. It will take a game or two, clumsily referring back to the instructions, before the cascade of eureka's take over your brain. Then you're off to hours of great fun.

Oware on the Lunar and Martian Frontiers

Perhaps the frontier version of this game will be known as "Craters & Rocks." The game may prove so popular a pastime in the "New Stone Age" that permanent game tables of molded concrete or cast basalt might become a common feature in frontier parks. [www.tradgames.org.uk/images/OlindaKaliyaTable.jpg] On the other end, individually crafted hinged boards folding for portability would be heirloom quality gifts. Since sets could be manufactured in quantity from pressed aluminum sheet, yet hand-crafted in clay, glass, cast basalt or other art media, they would serve all ranges of the market from beginner to devotee. The board and pieces can be easily be scaled up or down in size.

Getting in the Frontier Spirit

Where to find the rules, ready to use sets: Just go online to www.google.com and type in "Oware" and search. You will find all you need. Hobby stores, game stores, and museum shops may have sets for sale.

Let's rename the Lunar Frontier version of this game "Craters & Rocks!" Make your own out of clay, beaten tin or aluminum sheet, mold-poured plaster of Paris, paper maché, or wood. You might find a muffin/cupcake tin that will work. Download game instructions, and start playing.

Craters & Rocks would be great after-meeting fun for local Moon Society, National Space Society, even Mars Society chapters. At least we think so! **<MMM>**

Designing Surface Structures for Moonscapes & Marsscapes

by Peter Kokh

Introducing a touchy topic

Not all persons interested in a permanent human presence on the Moon and Mars share the same sensitivities when it comes to design with respect to site context. A bridge is a bridge is a bridge, say some, no matter where you plunk it down. No, say others, any structure should take in mind its visual environment when fine-tuning design details, or even in choosing between major design options.

Living in a 120 year old neighborhood in which a new replacement police station and library have recently been built without any visual allusions to the neighborhood context, as if they were dropped on site by some gigantic helicopter, I tend to side with the latter view. At the same time, to impose a narrow set of allowed styles can be quite suffocating. Variety is the spice of life, and *vive la difference!* So where is a reasonable middle ground? In plain fact, if there is to be a free enterprise economy, there will have to be some latitude in design constraints for structures that are visible on the surface of the Moon and Mars.

Relevant Readings from Past Issues of MMM

MMM # 55 May 1992

p. 5, "Skyscrapers on the Moon"

p. 7, "Moon Roofs"

MMM # 111 December 1997

p. 4, "Lunar Skyscrapers: Shattering Low Expectations"

MMM # 137 August 2000

p. 5, "Taking-Back-the-Surface Architectures"

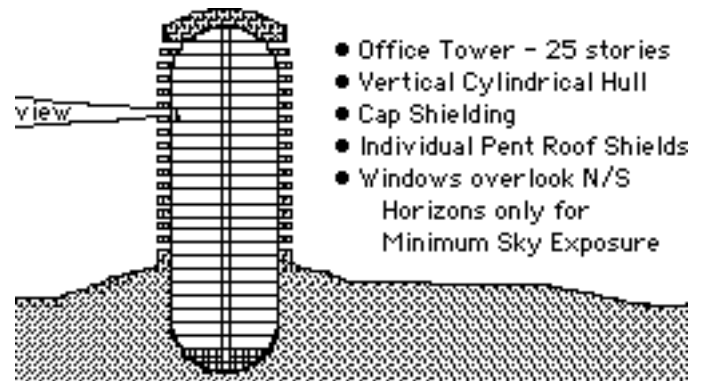
"Blend in" or "Stand Proud?"

One fight we can expect is between those who will insist that any structures built on the surface of the Moon or Mars - bridges, towers, signage, etc. - be designed to blend into the moonscape or marsscape, so as to appear "to rise out of it" so to speak, and those who believe that we should be proud of our achievements, and our surface structures should "stand proud" of the host landscapes. There would seem to be legitimacy to both points of view and we can expect to see examples of both come to being.

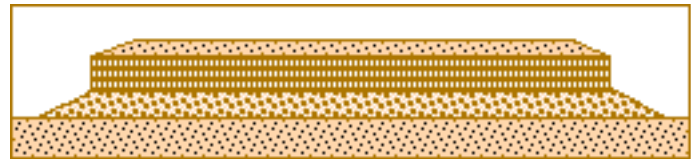
In the articles cited above, the very use of locally produced building materials, and the need to preserve radiation shielding integrity for all pressurized structures, does per se confer a language of distinctively lunar or Martian forms, shapes, and color schemes. If we build to address the economic need to work with local materials, and the life-threats of the host alien environments, this level of "blending in" is almost assured.

In "Moon Roofs" we detailed a number of ways of "dressing up" the regolith shielding mounds that cover our habitat structures: lime or titanium dioxide whitewashes,

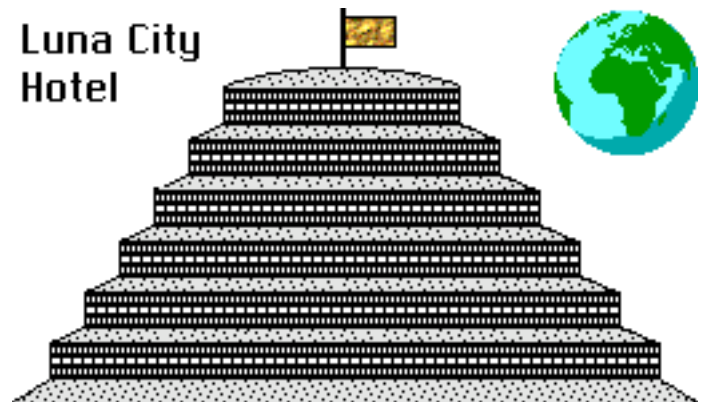
rust iron oxide, black ilmenite; cast basalt slabs, molded lunar concrete, etc. In the two articles on skyscrapers, we suggested individually shielded "pentroofs" for each floor, pagoda style, if you will. While such high rises would clearly bust the horizon, they would do so with shapes that would be distinctively appropriate for the planetary context. That, of course, does not address the question of whether or not they should be built at all. But we are sure that they will be, sooner or later. And in our opinion, this will be fine. They won't be towers of stainless steel and glass, Mies van der Rohe style, after all!



Pentroof Skyscraper on the Moon, from MMM # 55, p 5



Shielded building on Mars' surface, from MMM # 137, p. 6



Wedding Cake of cylinder sections from MMM # 137, p. 9

Clearly, when designing habitable structures on the Moon and Mars, the cited considerations will tend to result in buildings that "belong", yet "stand proud," a happy result. But what about other structures: bridges, communications relay towers, tourist observation towers, utility poles, road signs, and, yes, billboards? With no need to pressurize and shield, would not "form follows function" and the "most economic use of available materials" rule? One's first inclination may be to plunge into this debate adrenalin pumping and ready to fight. Let's do some background work *first*.

Just the facts: Available Materials

On the early lunar frontier available metals and alloys will include cast iron, low carbon steels, aluminum, and magnesium. Magnesium may become a favored material of architects and builders, given that in the lunar vacuum, oxidation will not be a problem, and it takes less energy to produce than aluminum. Stainless Steel would seem unlikely. Cast iron, the darling of the early industrial age on Earth in Victorian times, could be a staple for lunar architects and perform quite well in low lunar gravity. No protective paint would be needed. Exposed metals would lose their shine over time from micrometeorite bombardment. Designers will be keeping this in mind. Given these facts and considerations, a "language" of out-vac exposed metal use in bridges and towers may emerge that will be characteristically "lunar."

On Mars, high carbon steels should also be an economic choice, possibly stainless steel as well. Micrometeorite bombardment will be greatly reduced, wind-borne sand and dust abrasion being the greater problem. Here too, oxidation will not be a factor. Steam treated cast iron with rust coating could be used by designers and architects where "blending in" does not compete with a need for high visibility for safety reasons (structures that could become driving/flight hazards if not easily picked out by the eye.)

Sintered regolith and regolith blocks would retain the coloration of host materials on both worlds. Concrete, being based on lime cement, tends to whiten the sand and aggregate also used. Untinted cement would blend in quite well on the Moon, less so on Mars. That would be a safety plus for concrete paved roads on Mars. On the Moon, a row of cleared rocks and breccia along the shoulders, or maybe straight down the median strip, would be enough to clearly mark the route.

Cast basalt will be economically available in many areas of both Moon and Mars and retain the basic coloration of the original materials. Raw (no special formulation) glass or glassified blocks would do likewise. Tinted glass cladding, modern skyscraper style, would seem to be a foolish option, given micrometeorite rain on the Moon and sand abrasion on Mars. Durable cast basalt tiles, slabs, and sheets may be the best choice when "shine & sheen" is a design goal for the structure in question.

Economic Choices: the Bottom Line

On the Moon and Mars, as on Earth, the "bottom line" is something not to be dismissed. Sometimes designers have a "luxury allowance" for visual impact, especially when designing structures intended to become corporate icons, or urban "signature" edifices such as the Sydney Opera House, the Seattle Space Needle, St. Louis Gateway Arch, and the Milwaukee Art Museum's new Calatrava addition on L. Michigan (www.mam.org/site/photos/images/mam8.jpg) Such icon and signature structures will appear on the Moon and Mars as well, and I, for one, welcome them. Yet even here, among competing designs, economic choices may force

solutions that favor use of materials that tend to blend well with the host environment. Form is a different question, and especially for icon and signature structures, "standing proud" is likely to win any battle with "blending in" when both cannot be achieved together, as ideal.

The Mundane and Utilitarian

We will need road and railroad bridges, pipelines, utility poles, and communications relay towers. Economic motives are likely to be paramount. When will it be cheaper, and safer, to bury utility lines than to erect miles of posts? The solutions to those equations on the Moon and Mars, may not always be the same as they are on Earth. One consideration is Right of Way. Mars and the Moon are wide open, and right of way easements are unlikely to pose a problem or to constrain design choices and options.

When utility lines and pipelines follow highways, it would make sense to design each with the other in mind, if not in combination. Doing so might promise better visual results. When they do not follow roadways or passenger rail lines, but traverse seldom visited terrain, spending the extra buck to make them "blend in" will be unlikely.

Another consideration will be to balance the up front cost of construction alternatives with any lifetime maintenance costs. It has been common on Earth to discount the latter, i.e. for builders to "take the money and run." Hopefully, building in to up front costs respect for lifetime costs will receive much more attention on the frontier. It will cost so much more on the frontier to build anything, that the need to build right the first time should appear to be paramount to all. Cutting corners and costs are a hard tradition to break!

We intend to do separate articles on Horizon breaking superstructures on the Moon, and out-vac Signage.

Designing with respect for the Moon is not a case of the Moon's sensitivity. It is an inanimate object. Rather it is a case of our own sensitivity and our own inner need to feel connected, of respect too for the adopted world's aloofness and mindless hostility to life. It is out of our desire to belong to the Moon, and to be her children as we were those of Earth. Not all people are sensitive to such things, but we think that the desire for connectivity will be quite common among those who choose to forsake Mother Earth to be pioneers and settlers. The same for Mars.

The Reds, the Grays, and the Greens

Kim Stanley Robinson coined the word "Reds" as a Martian frontier counterpart to our own "Greens." The "Reds" opposed terraforming, and wanted to preserve the character and integrity of Mars while finding ways to live on their new frontier in harmony with it. One can expect that on the Lunar Frontier, there will arise a "Gray Party" similarly concerned with maintaining a human presence on the Moon that pays respect to our new home. <MMM>

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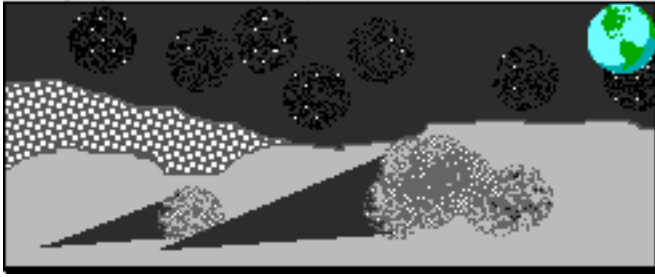
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Nightspan Life – Out on the Surface!

"It was the nights before sunrise, and all through the town, moon folk kept cozy and busy deep down. But out on the surface, not a creature was stirring, not even a miner." Not! As forbidding as it may seem to be out on the surface during nightspan, some Lunans will venture out there for work, others for play and recreation. It's all part of learning to be at home. See pages 4-8.

Frog and Hostel, Part III

The Hostel's Role in the Division of Labor

© 2003. J. Craig Beasley < bginstitute@ev1.net >

The Hostel: Provisioning the Lunar Log Cabin

In writing the Frog and Hostel (F&H) paper [1] for ISDC '91, Peter Kokh had four principal objectives:

1. Define the logical division of functions between visiting vehicle and shelter; how these differ with the particular purpose of the hostel and the prospects for its future.
2. Define design constraints on the visiting vehicle. Co-designing this vehicle will be necessary if the potential of the hostel approach is to be realized.
3. Outline logical paths of evolution towards stand alone status for the Hostel.
4. Examine possible architectures, whether for pre-fabrication on Earth or for construction on the Moon using native materials.

This is one of the things that is the most attractive about the F&H method, its pre-planned evolutionary configuration. It meets the need of true habitation of a frontier as it is transformed to fit the environment. The technical key for this approach, in my opinion, is to keep the expansion and reconfiguration of the system as open as possible. This means designing the structure and geometry of both halves of the system to accept "black boxes" of generic size, shape, and mass, at least as much as possible.

We will focus on the Hostel Division of Labor, the second half of the first objective. [See Box at end of this article for items detailed in original paper]

At first, the triple stack SpaceHab Moonbase [2] would house space-intensive functions, such as:

1. "Bedrooms" with Personal Computer Networking.

Certainly, the bedrooms would be merely curtained or portable wall sections of the Hostel, to allow for some small measure of privacy. In a space as small as a Hostel structure, any concessions to privacy may be considered frivolous luxuries. However, even a small allowance of personal space may go a long way into taking care of the psychological needs of the crew during a four-week stay.

Personal terminals would connect in these bunking spaces, linked to the computing hardware in the office and multimedia library areas of the Hostel. Given the ample multitasking capabilities and relatively low mass of today's computers, there should be no reason to have separate computing facilities in the Hostel.

2. Lounge/Dining "Ward Room"

As important as privacy may be to the individual crew members, the flip side will be the avoidance of loneliness and disconnection. A common meeting area will minimize the impact of this flip side. The Ward Room would be near the available galley, and would consist of comfortable but practical seating around a worktable and a display device for computing and communication. This arrangement would allow teleconferencing and recreation at the display center, and be a common area for group meals & discussion.

3. Exercise Room

Since the cislunar transit portions of the mission will be very short, it's unnecessary to have exercise facilities in the Frog, but the much longer stay on the surface lends exercise a much higher importance. A simple stationary bicycle or treadmill and a resistance training system would appropriately be located in the Hostel.

4. Project workstations

A set of dedicated work areas will be vital for projects during the missions. Each workstation would provide a stable working surface to perform repairs, build experimental apparatus, and study samples of lunar materials. Storage areas would also be included for the sorting and protecting of items in work. These work stations could be a set of enclosed secure cabinets with a fold-down worktable at each location.

5. Panoramic visual access to the outside.

If this is not in the original landing stack, then it will become a priority for subsequent havens planted on the Moon. Depending on how the Hostel is oriented on the lunar surface, windows already built into the SpaceHab modules would serve this purpose. Of course, the dream is to build the Lunar Hilton with expansive windows overlooking the magnificent desolation, but that will be for another time.

6. A robust shield hangar and habitat cover.

This substructure item could be stowed inside the Hostel for later external deployment, in sections easily snapped together during an EVA, once the Hostel is anchored to its site. This would provide an excellent storage

shed for equipment and materials that would otherwise clutter and contaminate the habitat, such as rover vehicles, earth moving tools, and geological bulk samples.

For expansion, the hostel could be designed for the mounting of additional structures [3], allowing a broader network of structural anchors for a "downtown district".

** Of course, all of these ideas are coming from the brain of this writer (J. Craig Beasley,) and are by no means the end-all of the provisioning tasks for the Frog-and-Hostel system. Reader comments are highly encouraged in this quest to optimize the F&H system. The architecture of the whole F&H concept is in many ways a study of a process, not merely the design of two vehicles. Each half of the system will shift and change as the needs of the mission change, which is as it should be. Living and working on the Moon will need human & hardware flexibility.

NEXT - The Frog and Hostel Over Time: Give and Take

EDITOR'S FOOTNOTES:

[1] **The Lunar "Hostel:" An Alternate Concept for First Beachhead and Secondary Outposts.** Peter Kokh, Douglas Armstrong, Mark R. Kaehny, and Joseph Suszynski © 1991 The Lunar Reclamation Society, Inc. http://www.lunar-reclamation.org/hostels_paper1.htm This paper was published in its entirety in **The Proceedings of the 10th Annual International Space Development Conference, San Antonio, TX, May 22-27 1991**, pp. 75-92. ISBN 0-912183-05-5 Univelt, Inc. San Diego, CA

[2] The original paper described several "big dumb volume" architectures that could fly compacted in a Space Shuttle payload. The hybrid rigid-inflatable "donut" design that may have inspired NASA's TransHab was one of these, and the one favored by the authors.

[3] As the "donut" alias "moonbagel" (and TransHab inspiring) architecture has a circular "footprint", two additional "docking ports" at 120° apart would enable adding additional similar units on a hex-grid pattern.

Initial Hostel (Big Dumb Volume) Functions

www.lunar-reclamation.org/hostels_paper1.htm

- Bedrooms, Lounge, Office, Chapel, etc.
- Main antenna, possible ham equipment
- Personal computers in quarters
- Main radiator bank
- Main power generation equipment
- Open-vac rover
- Surplus compressed H₂, O₂
- Main dining area, all meals
- Departure dehumidify/bake cycle
- Laundry drying
- (no initial plumbing) composting toilets, waste banking
- Pantry for standby rations, snack bar
- Infirmary space (future diagnostic/major procedures)
- Dry space-needling workstations
- Sample sorting, display, storage
- Panoramic exterior visual access
- Interior solar access, heliostat
- Space-needling exercise area
- Bedroom consoles, lounge console
- Accumulating library, collections

Mare Frigoris Base Site Looking Better:

Ice at the Moon's Poles Extends to Lower Latitudes than Expected

"Craters as far as 20° away from a pole still have significant amounts (22-27%) [of] permanent shadow."

Source: "The Moon's Dark Icy Poles"

www.psr.d.hawaii.edu/June03/lunarShadows.html

Quotes from the report

"Especially at lower latitudes (down to 70°), larger craters have slightly more relative permanent shadow than smaller craters. Craters nearer a pole (see the 90° red line) contain a larger percentage of shadow than craters at 70°. But more than crater size, they found that latitude is the dominant parameter affecting the amount of permanent shadow in a simple crater. Craters as far as 20° [377 mi. = 607 km] away from a pole still have significant amounts (22% to 27%) permanent shadow.

"Illumination of a 20-km-diameter (32 mi) crater was simulated for winter, equinox, and summer days. The amount of permanent shadow inside the crater corresponds to the value for a day in summers. Armed with these simulation results, a "permanent darkness" equation can be deduced that yields shadow amounts as a function of latitude and crater size.

"Their next step was to examine images of the Moon and identify all the fresh looking simple craters larger than 1 km (5/8ths mi.) within 12° (227 mi. = 365 km) of each pole. By measuring the diameters of these craters and using the "permanent darkness" equation they calculated the amount of permanent shadow."

Original Reference: Bussey, D.B.J., Lucey, P.G., Steutel, D., Robinson, M.S., Spudis, P.D., Edwards, K.D. (2003) Permanent shadow in simple craters near the lunar poles, *Geophysical Research Letters*, v. 30(6), 1278, doi: 10.1029/2002GL016180.

Implications for siting of a permanent lunar settlement - Ed.

While everyone else strongly supports a South Polar site because of its unique Mt. Malapert "the Peak of Eternal Light" (in the light only 87% of the time, and not at the same part of the peak; rugged terrain, ultra-long ever-changing shadows, very remote from nearest mare areas - all very serious drawbacks in our opinion) we continue to favor a northern site, along the N coast of Mare Frigoris.

Now we feel even stronger in this conviction, as this study points to several craters near the Frigoris north shore that should have ample ice reserves, less than a 10th as far away as is Mt. Malapert from the nearest southern mare shore. For industrial purposes a highland/mare shore site is ideal, and anything else risks being an assured dead end, including Mt. Malapert at the South Pole. <PK >

NIGHT SHADOWS

by Peter Kokh

On the cloudless, airless Moon, the Sun shines with full industrial strength brilliance. And without an atmosphere to scatter light everywhere, any shadows are ink black. Unless there is sunlight bouncing off a nearby rock or ridge, it is of little use trying to peer into them to catch a hint of what lies hidden there.

But the nightspan moonscapes are hardly a total extension of these black lightless pools. When the sun is up, the glare is so bright, that it is difficult to pick out the stars in the black skies. But as the sun sets, the other lights in the heavens come out to play, with a steady intensity never seen on Earth.

On Earth, the stars are not bright enough to cast shadows detectable by the human eye. And when the Moon is up, it's much greater brilliance rules. The Moon does cast shadows on Earth. Indeed, one can read a book by the light of the full Moon.

Nearside Nights on the Moon

Back to the Moon. It's "nearside" is always turned towards Earth and so the Earth is always in the nearside skies - with three and a half times the apparent diameter, covering thirteen times as much sky, and, thanks to clouds, snow and ice, shining, phase for phase, with sixty times the brilliance. On Nearside nights, Earth-cast shadows will be pronounced and you will be able to see the unshadowed moonscapes quite well. The apparent diameter of the Earth being nearly four times as great as that of the Sun, the edges of shadows cast by Earth will be considerably less sharp than those cast by the Moon.

Farside Nights on the Moon

Between Nearside and Farside, there is a 14 degree slice (the limbs) which alternately wobbles into and out of view of Earth. But in Farside proper, Earth is never above the horizon. So when the sun is down there are just unimaginable myriads of stars. The brightest "objects" will be the planet Venus, and Jupiter as a poor second, and Mars when its orbit brings it close to Earth. In the cloud free, haze-free, airless nightspan skies could Venus cast shadows?

Possibly, but there is something else to consider. In the Farside, the Milky Way band of light circling the heavens, our own galactic disk seen edge on from our inside vantage point, will shine with an "experience of a lifetime" splendor, drawing many tourists from Earth. Will the billions of stars in its clouds and swarms of this horizon to horizon stretching band tend to wash out any shadows cast by Venus? I wouldn't know how to calculate the Milky Way's aggregate apparent magnitude, But it would seem that the Farside moonscapes would be clearly but faintly visible in this symphony of lights, but vastly darker than Earthlit nearside terrain. Nightspans on Nearside and Farside will bear no comparison to one another. <MMM>

Out-vac Nightspan Life on the Moon

by Peter Kokh

As the Sun Slowly Sets

For the previous two weeks, the unlikely pockets of humanity on the Moon will have been beehives of activity, making use of the Sun's heat, its life-giving rays, and its electrical generating potential, to work through the more energy intensive portion of the long list of tasks needed to keep the community going. All the while they will also be exercising the habit of "energy husbandry" to convert excess solar into reserves of potential energy to be tapped during nightspan. Even so, total available on-line power will drop markedly as the Sun finally reaches the west horizon.

Finally, the great solar furnaces and turbines will be shut down and the activities they support will stop. Those industries that depend indirectly on abundant electricity generated by solar arrays must likewise phase down. For whether supplied by standby nukes, fuel cells, spinners, or closed loop hydroelectric systems, the total amount of on-line electrical power will be likely be appreciably reduced for the fortnight to come. Industry after industry will switch gears, taking up now those more labor-intensive tasks strategically postponed during dayspan. The Sun will next rise in 354.367 hrs or 14.7653 days.

For many industries the emphasis will shift to maintenance, repairs, and change out of equipment. For many workers, it will be rather like switching jobs every two weeks. And perhaps that will be a welcome break in the routine, an anticipated periodic shot in the arm, essential in sustaining personal and communal morale.

Workers who by dayspan crew industries that do not have a proportionate list of postponable energy-light labor-heavy tasks to keep them busy during nightspan, might shift to quite different company co-owned ventures that are task-lopsided the other way. Among those will be some surface activities that require little energy and a minimum of light.

The Sun now set, Lunans, temporary personnel and permanent settlers alike, may have more scheduled leisure time. Some of them may want to spend a portion of that time on the surface. Probably, most will not. Out-vac spaces in and around the settlement that were scenes of moderate to busy activity during dayspan will seem eerily quiet, like our own urban cities and towns in the wee hours before the first rush of morning traffic. To us early birds, the world suddenly appears quiet, especially friendly, all our own. It may be so for those who relish venturing onto the surface after the long sundown (the sun will take 30 times as long to set on the Moon as it does on Earth.)

Sulfur lamps will provide a minimum of lighting, much as standby emergency lighting does in our factories and office buildings during a power outage. Just enough to find your way, not enough to work by.

Nightspan Out-vac Activities

On the Moon, the nightspan is 14.75 days long, 30 times as long as an average terrestrial night. Sunshine is the principal readily tappable local source of energy on the Moon. Its unavailability during nightspan makes the Moon a forbidding place to many people with low pioneer spirit quotients [PSQ]. In every frontier of the past, pioneers found themselves challenged by the unavailability of various things they had taken for granted "back home." Those who survived, did so by turning to their inner resourcefulness; they "found" ways, not just to make do, but to thrive. Lunan pioneers with the right stuff will learn not to fear the night, but to love it and cherish it as an equal movement in life's rhythms.

We will not earn the right to say we have a permanent human presence on the Moon until we have learned how to enjoy and relish what most Earthfolk would fear. We have to take back the lunar nightspan from the dread bogeyman of the energy desert that will test our metal.

It's all about learning to live on the Moon, on the Moon's own terms. On Luna, do as the Lunans do! On Earth we have many examples in Nature of plants and animals who have seasonal changing rhythms: squirrels, birds, bears, the list goes on and on. Their daily rhythms adjust to sometimes drastic changes in the environment.

Out-vac Nightspan Jobs

The various items of equipment needed to convert excess solar energy into potential energy that can be tapped at night will need maintenance from time to time, and nightspan is the ideal time to give these chores full attention. The same goes for mining equipment and any machinery used in processing and manufacturing that is situated out on the surface, exposed to vacuum.

Other Nightspan Out-vac jobs may include surface warehousing, tending observatories and other scientific installations, and jobs involved in transportation and shipping. Field work such as surveying, road construction, and prospecting will largely cease. An exception may be blacklight prospecting, in the earthlight shadows, *if* the use of ultraviolet lamps proves to be useful in detecting certain desirable minerals.

Nightspan Recreation

An all-bases-covered strategy for squirreling away enough sun-derived power to allow the settlement to keep productively busy with energy-light and labor-intensive tasks during nightspan is not our topic, and had been covered elsewhere [MMM #90 p. # NOV '95 pp. 7-8 "OVERNIGHTING: Consummating the Marriage of Moon & Base."] Most pioneers will find ways to keep busy in this fashion in the private and common (middoor) settlement spaces below the regolith blanket that shields them from the cosmic elements. But others, like night-active animal species on Earth, may look forward to a chance to "go out

and play" (or work!) with the Sun safely below the horizon, unafraid to deal with the Moon as it is.

Even if UV "blacklight" lamps prove to be of little or no use in prospecting, amateur rock collectors may find them useful in searching earthlight shadows for "pretty" rocks, especially in locations closer to the limbs where, the Earth hangs lower in the sky and earthlight shadows will be longer. For Farside settlers and persons on tours of duty, it may be considerably more popular, given the total absence of earthlight. This hobby activity would be moderately expensive - spacesuits must be purchased or rented.

Even at night on Nearside, a dazzlingly brilliant Earth always in the sky, there will be shadows. Possibly a game of shadow hide and seek would enjoy some popularity. Others will simply enjoy cruising the Earthlit moonscapes, finding in them a beauty absent in the glare of the untempered sun. (The light of the Full Earth will be eighty-some times as bright as the Full Moon we enjoy.) Tourist excursions may take coachloads of pioneers out onto the roads surrounding the settlement for just such enjoyment. There may be a Sunrise/Sunset Chasers Club in which people travel to see the sun rise or set from spectacular locations such as crater rims. There may be motoring clubs for those who enjoy nightspan road rallies. Some may prefer to ride in spacesuits in open-vac rovers or ATVs. IR night vision goggles may be common equipment.

Will pursuit of amateur astronomy take settlement dwellers and others stationed on the Moon out on to the surface? Peering through an eyepiece while wearing a helmet would seem to be discouragingly cumbersome, so it seems more likely that ways will be found to bring star and planet images safely indoors without loss of quality so that they can be studied and observed in shirtsleeve comfort. And for this activity, whether it is dayspan or nightspan will make no big difference as telescopes can be designed to baffle out the Sun's glare, exposing black heavens.

As settlers become more at home ...

For many persons living in sunnier, warmer climes, the idea of outdoor winter sports (here on Earth) seems forbidding, something to watch on TV from the snug safety of comfortably warm indoor lairs. Even for many more hardy northerners, winter sports are for kids and others. But there are a surprising number who have learned to enjoy winter, even look forward to it. Not just the beauty of fresh-fallen snow, but for the thrills of skiing, tobogganing, skating, snowmobiling, etc.

On the Moon, perhaps most settlers will be quite content to find nightspan diversions and recreation safe inside their comfortable regolith-shielded homesteads and middoor spaces. But there will be some who will make a point of venturing out-vac, even during nightspan, and finding ways to enjoy themselves. The challenge alone will beacon them. Perhaps you will be one of these. < MMM >

A Word about Nightspan Moonsuits

Spacesuits designed for EVA in Earth Orbit (Shuttle and Space Station activities) are designed to walk a tightrope between searing sunlight and the intensely deep cold of space while in the shadow of the Earth. Typically, an astronaut space-walker will be in sunlight about an hour give or take, then in shadow for a similar length of time, back in sunlight (depending on the height of the orbit), back in shadow, etc.

In contrast, the Apollo moonsuits were designed for midmorning lighting conditions on the Moon. [MMM # 90 NOV 1995, p 7. OVERNIGHTING on the Moon, P. Kokh] It was never NASA's intention to have personnel on the Moon in midday or afternoon high heat conditions, much less at anytime between sunset. and sunrise!

Now there will always be some demand for "wear anytime" moonsuits. But for many dayspan only or nightspan only users, suits maximized either for heat rejection (day suit) or for heat retention (night suit) will provide superior performance and comfort.

We have written previously about the need to face head on the midday lunar heat. [MMM # 115 MAY '98 p 8. "HIGH NOON: Coping with Dayspan Heat," P. Kokh} After all, what kind of economy could we have if we confined our surface activities (prospecting, settlement and road construction, mining, exporting and importing, etc.) to a few days early in the two-week long dayspan? Similarly, what kind of an economy could we build if no one dared venture out on the surface during the equally long nightspan?

We do not pretend to know how to maximize a suit for heat retention. But the problem is much simpler than it would be if there were somewhere on Earth equally cold conditions, $-200^{\circ}\text{F} = < -90^{\circ}\text{C}$, and colder yet for those working in permanently dark lavatubes or polar craters, $-315^{\circ}\text{F} = -193^{\circ}\text{C} = 80^{\circ}\text{K}$. Why? On Earth the dominant chilling force is convection, heat carried off by the air and wind. On the airless, windless Moon we have heat loss only by radiation to cold surfaces and the near absolute zero cold of space itself. (Ignoring convection losses through the soles of moonboots, of course.) An inward-facing silver lining would work to retain body heat.

Have such suits been developed? It would seem unlikely, there never having been a planned need for them. But there seems no need to fear the cold of night, even if our not-so-well prepared astronauts have reported feeling the "bone-chilling cold of space" while engaged in EVA in the shadow of Earth while working on the Station, Hubble, or other piece of hardware.

Read also this previous article:

- MMM # 151 DEC. 2001, p 3. Engaging the Surface with MOON SUITS instead of Spacesuits, P. Kokh

Around the Campfire

Since time immemorial, ever since the taming of fire, we have found warmth, comfort, and company huddled around campfires and hearths. The fireside has been the most social of places, the place where stories were told, myths and legends learned, mighty feats planned, and dreams made. It is the "hearth" that has been the traditional "soul" of the home. In some languages "hearth" and "home" are one word. Nestling around the fire is something we all enjoy. But however infrequently enjoyed, the magic of the controlled fire is universally so positive an uplift that it is possible to wonder: "can it be humanity if there is no campfire?"

Yet on worlds without oxygen-sweetened atmospheres such as the Moon, open fire is not possible. We'll have to huddle within the very limited atmospherules of mini biospheres in which open fire cannot be tolerated.

Yet this gloomy verdict may only apply to fires in which the combustion products are smoke and toxic gasses. For Out-Vac campsites, it should be possible to devise a tightly confined hearth stand in that slowly feeds together pure hydrogen and oxygen. With burning confined to a nitrogen-free chamber, the only combustion product would be steam, pure water, usable for drinking or other purposes. What we are talking about is a modified fuel cell, in which the $(2)\text{H}_2 + \text{O}_2 = (2)\text{H}_2\text{O}$ reaction is run somewhat faster, not so fast as to be explosive, but fast enough to sustain a flame, perhaps with a harmless enough additive (if one can be found!) to colorize the normally invisible H+O fire.

I'd be surprised if such a device now exists, or a market for it - not back here on the open air, open sky Earth. But out on alien shores, a flame-in-a-jar contraption might create enough symbolic warmth and cheer to become commonplace. For the wanderlust-driven, owning such a pocket hearth could be a real psychological enabler. See the ad in the employment wanted section: "Have fire chamber, will travel - anywhere!

* The above is an edited and abridged version of an article that appeared in MMM # 52 FEB '92, p 6. The FIRESIDE, P. Kokh. Also published in MSFire Fanzine, Vol. 2 #5/6, Fall 1996, online at: www.uwm.edu/~schamber/MSFS/MSFire/Vol2No5-6/fireside.html

Relevant Readings from MMM back issues

- MMM # 7, JUL '87, "POWERCO" [MMMC #1]
- MMM # 31, DEC '89, pp. 3-5, "Ventures of the Rille People" (Prinzton design study), V. * Multiple Energy Sources. [MMMC #4]
- MMM # 43, MAR '91, pp. 4-5. "NIGHTSPAN" [MMMC #5]
- MMM # 90, NOV '95 pp. 7-8 "OVERNIGHTING: Consummating the Marriage of Moon & Base" [MMMC #10]

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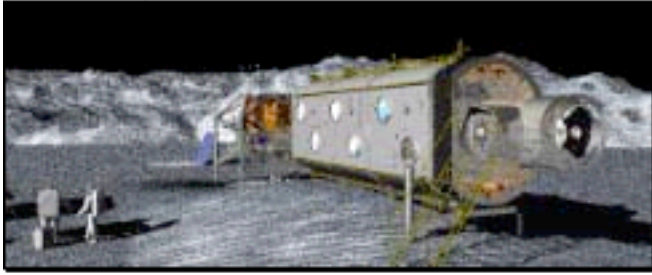
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Redesigning the Artemis Moonbase EVA Module

The currently favored design for the proposed Artemis Moonbase™ starter module, a triple SpaceHab unit on a footing with an attached EVA-Docking Module, has rested on the shelf collecting cobwebs for a few years now. Editor Peter Kokh takes a second look at this latter module in this issue, and finds some major problems that need attention. For details, see *below*, pp 47-48..

In FOCUS: 📺 Blackouts “Inconvenient on Earth, “Catastrophic” in Space

To many people, in many ways, the recent major blackout experienced in parts of the U.S. Midwest, Northeast, and in much of Eastern Canada, was an eye-opener. We leaned that in this advanced day and age, now in the early 21st Century, much of our electrical power transmission grid system is vulnerable to “accidents” caused from within, a symptom of aging infrastructure. No one seemed to think it could happen, but it did.

How we should address the situation, or whether we will just let it slide hoping that it was a one-time quirk, is not our topic. For those of us who want to see human civilization transplanted to various locations on the space frontier, there are more immediate lessons.

It struck us how our lives have changed since the last great northeast blackout: we have become, not just as a society, but as individuals and families, computer-dependent. The Internet looms as the “noosphere” foreseen by the Jesuit philosopher of evolution, Teilhard du Chardin. Many of us would consider ourselves naked and helpless without our cell phones. Not only did the lights go out, and the refrigerators grow warm. No television, no computers, no Internet, diminished cell phone service. Egads!

How dependent we had become on systems plugged into the power grid was for many of us, even more of an eye-opener than that our power transmission grids might be woefully inadequate to meet today’s growing power demands. It was not just inconvenient. It was something we are not willing to tolerate again. It stopped too much of our day-in, day-out taken-for-granted activities. The blackout dared stop us in our tracks.

For all that, it was still no more than a temporary

inconvenience for most involved. Some things went on. We could still breath the air - it didn’t get stale. At least some people in the blackout area still had tap water. Air-conditioners stopped, but it neither got unbearably hot nor very cold. We were temporarily thrown back to a pre-electric age, and age where once people everywhere carried on quite well, thank you.

How would a similar incident play out in a space settlement, in a lunar outpost, in a Martian frontier town? The air would stop circulating, for one thing. In these small closed mini-biospheres, where everyone will live essentially downwind of themselves, the air would quickly grow foul, saturated with carbon dioxide, suffocating.

If the event happened during sun-up hours, sunlight funneled in through heliostats and “light pipes” would make the loss of artificial light a mere inconvenience. During nightspan or sundown hours, it would be more of a problem. Candles would quicken the rate of air quality deterioration. Obviously, backup “off-grid” power sources would have to snap into action, turned on by the very loss of current, much as emergency generators here on Earth.

The principal point is that here on Earth, the biosphere keeps on ticking. On the space-frontier, artificially established mini-biospheres would be totally dependent on electrical power. Any blackout would be a potential catastrophe from which there might be no recovery, if it lasted more than a relatively short time. Our concern is that on the space frontier, we cannot allow a blackout to happen at all. “Rarely” will not be good enough. That has implications for how we design our space frontier power systems.

Space activists are no different in their lack of agreement from other persons who have strong opinions on energy matters. There are the pro-nuclear, antinuclear, and balanced systems proponents. Hey, time-out! Number one consideration is to eliminate the possibility of a blackout in a space frontier community, barring a direct asteroid impact or other “act of God.” Posturing must come second.

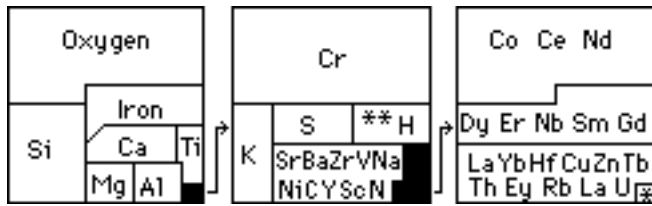
Nuclear energy has a place, especially given the absence of in-place biospheres and ready quarantine. But reliance on nuclear power alone seems stupid. Show me the nuclear system that has never gone “down!” There is abundant solar power available everywhere in the Inner Solar System, including Mars, and it will be foolish not to tap it when and where available. It will also be foolish not to store excess sun-up solar power to use as back-up and extra power for periods when sunshine is not available. Let us harp once again: we must learn how to overnight on the Moon. Placing an outpost in one non-typical spot, to avoid the challenges of overnighting, risks “beaching” the effort to open the Moon in a cul de sac. More on this soon.

Posturing increase the risk a catastrophic blackout in space frontier settlements. Let’s get on with the no nonsense planning of well-rounded energy generation infrastructures for big and small frontier outposts alike! - PK

Smelting Moondust: seeking a Simpler Process to produce the stuffs for Lunar Industry from Regolith

by Dave Dietzler < pioneer137@yahoo.com >

Various processes have been described for extracting pure silicon, cobalt, nickel and other elements from regolith. These usually use fluorine, carbon monoxide and other reagents. In this article, a simpler yet still speculative system is described for production of large masses of useful materials like glass and cement from lunar regolith. The simplest process involves using solar heat to produce cast basalt or fused regolith for bricks, pipes, tiles, road paving slabs, and everyday items like bottles or flower pots.



Most Abundant, Less Abundant & Trace Elements
in the Lunar Regolith (surface dust & rubble blanket)

Cast basalt: early lunar workhorse material

Cast basalt could be the cheap lunar material that does almost everything. It may even be possible to 'weld' cast basalt items together with a hand held electron or microwave beam gun. A mason could take a cast basalt brick, heat one side until it glows red and stack another brick on top of it which then fuses together. In this way, brick walls could be erected inside pressurized habitations. The only drawback is that this type of wall may be much harder to remove than one made of mortar-bonded bricks.

Materials other than cast basalt are also desirable. The nuclear powered automated Helium-3 mining machines will produce a steady supply of volatiles [a]. Similar machines that are fully automated or teleoperated by humans will shovel up regolith and deposit it in onboard furnaces that roast out the volatiles. The roasted regolith will then be sent to an onboard electrostatic belt separator to remove free iron and iron oxide fines and ilmenite grains. The rest of the regolith will be dumped.

Iron, titanium, and other alloys

When the machine's hold fills up with iron and ilmenite it will head back to base. It will transfer its load to a furnace where hydrogen and solar heat are used to reduce the oxides of iron and ilmenite. Iron, titania and water will be the main products. Iron will be separated from titania simply by using magnets. The water will be electrolyzed to recover hydrogen and obtain oxygen. The titania (TiO₂) will be sintered to make heat shields and high temperature refractory items including rocket nozzles perhaps. Titania will also be refined through electrolysis to get titanium metal and oxygen.

Iron will be cast into many different forms. Iron

products will not be very heavy in the low lunar gravity. There will only be the strange feeling of inertia when massive but seemingly light iron items are moved around. Outside in the vacuum, iron will never rust. Steel is still much more desirable than iron. It is far stronger and more corrosion resistant. Imported carbon will be combined with iron in a solar or electric furnace to make pure steel. A ton of carbon can make 300 tons of steel, so expensive imported carbon will go a long way [b]. Since 95% of the metal used on Earth is steel, we can expect to use the same percentage on the Moon [c].

Most of our Moon mining might consist of mobile mining machines rolling around gathering up volatiles and iron. We will also dig huge pits into the deeper volatile-poor layers of regolith with drag lines and 'steam shovels,' separate the iron with electrostatic belt separators and fill the pits back in with 'de-ironed' regolith. Then we will follow the procedures described previously to get iron, steel, titanium and oxygen.

Glass Production

Transparent glass rather than dark cast basalt, pourable cement, plaster, concrete, grout and other materials are also desired. 'De-ironed' regolith will be conveyed to a tank in which it is leached with sulfuric acid. The acid will break up the silicate minerals. Metallic sulfates will form in the solution. Silica, which resists sulfuric acid, and slightly soluble calcium sulfate (gypsum, plaster of Paris) will be filtered out through an asbestos or glass fiber filter. The silica and CaSO₄ will be dried. This mixture will then be separated either through washing or unmixing in the molten state to get pure silica for glass and CaSO₄ for plaster and a minor cement ingredient.

Slag cement and other products?

At this point, I confess to going out on a limb. Molten silica and CaSO₄ might react to form slag-SiCaO₃ and sulfur trioxide gas. Sulfur trioxide can be simply mixed with water to reform sulfuric acid and ground slag is actually a good cement ingredient. Slag cement is used commonly these days[1]. Washing would remove the CaSO₄, but because only a few grams of this compound dissolve in a liter of water and we can't just pipe river water through the mixture as we can on Earth; we' would have to use recycled water and this would require lots of energy and time. Waste heat from nuclear reactors or free solar energy might make this feasible.

Glycerol will dissolve calcium sulfate up to 1% of its mass. This is several times better than water[2]. Glycerol could leach out CaSO₄ and then be distilled and used again to leach out the CaSO₄ until all the 'gypsum' was removed and pure silica remains. Glycerol is distilled all the time in the soap industry so there is nothing unconventional about this. There may be other solvents to employ. Catechol (1,2 dihydroxybenzene) and basic ethylene glycol have been

shown to dissolve silica. [3] It might be possible to leach the silica out of the mixture with one of these organics.

The silica and "gypsum" can also be mixed with carbon powder and roasted in a solar furnace to reduce the CaSO_4 to CaO or lime as is done in the Muller-Kuhne process. [4] The mixture of silica and lime when water is added will make mortar. The addition of 5% gypsum, gravel and raw dirt when water is added will produce concrete. Some sodium oxide could also be added to the silica/lime mixture and solar heat could be applied to make transparent conventional soda-lime glass. More work needs to be done involving the manipulation of the silica and gypsum mixture to get materials in the desired proportions.

The remaining solution of sulfates will be roasted, boiled down and dried with solar heat. Water, unreacted sulfuric acid, phosphoric acid formed by the reaction with phosphate rocks, HCl and HF formed by the reaction with fluorapatite and chlorapatite, will be distilled and decomposed to obtain phosphorus, fluorine and chlorine.

The sulfates of aluminum, magnesium, manganese, chromium, sodium, potassium, any titanium not combined with iron in the form of ilmenite, and trace metals will be mixed with carbon dust and heated in a solar furnace. This will reduce the sulfates to oxides and generate SO_2 and CO that will be recycled to maintain acid and carbon supplies. The next step will be to reduce the oxides with carbon and even more heat to get free metals. Temperatures of 2000-2300 °C will be required. The solar furnace reactor vessel will be made of tungsten or an exotic ceramic that resists attack by the molten substances and gases it contains.

Alumina has been carbothermally reduced with solar heat experimentally on Earth at the Colorado School of Mines [5]. Although there are challenges for this process and electrolytic production of aluminum is cheaper, the use of solar energy for carbothermal production may become competitive. On the Moon, solar energy is reliably available and more intense than on Earth beneath our hazy atmosphere. The Sun moves across the sky more slowly on the cloudless Moon and this makes aiming mirrors easier. Moreover, aluminum only costs about one dollar per kilogram on Earth. Importation on the Moon would cost hundreds or thousands of times more than this, so processes deemed uneconomical on Earth will be worthwhile on the Moon.

Although carbothermal reduction requires a lot of energy, sunlight is free and this process is much less complicated than electrolysis and it doesn't require any cryolite which is unavailable on the Moon. It takes less energy to reduce the other metal oxides in the mix than alumina and just a bit more heat to reduce the magnesia.

Sodium, potassium, zinc, cadmium, selenium and other trace elements will be boiled out of the metallic mass and distilled at 907 °C (the boiling point of zinc) and lower temperatures. Zinc is purified typically by distillation so there is nothing unusual or untried about this. Magnesium

metal will evaporate at 1120 °C and manganese will boil at 2095 °C. The Pidgeon process and the Magnetherm process use silicon to reduce magnesia and the magnesium is released as a vapor which is then condensed to get the pure metal, so there is nothing too far-out about distilling magnesium. Some aluminum vapor will also form. Recovering aluminum vapor, manganese vapor and preventing carbide formation in the solar furnace will be a challenge for engineers in the future. [see footnote A] The remaining mass of aluminum with some magnesium and small amounts of chromium, manganese and titanium will form an inexpensive lightweight alloy that can be used for low stress applications like cans, bottle caps, jar lids, small parts, toys, furniture, sheet metal, and possibly hybrid rocket fuel.

If pure Al, Mg, Cr and Mn are desired, it should be possible to boil off all the magnesium at 1120 °C and use carbon monoxide to form carbonyls of Cr and Mn that can then be extracted with organic solvents. Chrome and manganese are good for alloying steel. Zone refining, a process that doesn't require any reagents, could be used to purify the aluminum even further. Aluminum with 99% purity may be desirable for wiring; however, it will be much cheaper to simply end the process with a multipurpose alloy as described in the previous paragraph for use when something lighter than steel, more corrosion resistant than iron and easier to work into shape is desired as is the case with a food or beverage can. [see footnote B] Lots of cheap aluminum for rocket fuel is also desirable, considering that enormous tonnages of it will be burned. Magnesium is also a candidate for rocket fuel. Purity isn't so important for stuff we intend to burn. These metals could be vaporized and sprayed from a nozzle to form fine droplets that cool by radiation in the lunar vacuum. The powders of aluminum and magnesium could be mixed with LOX to form a monopropellant. There may be other ways to burn Al and Mg in rockets too.

There are several bright spots in this process. Fluorine, chlorine, phosphorus, sodium, potassium and zinc are acquired without any great difficulty. Very few reagents are needed—just sulfuric acid, carbon, hydrogen, water and perhaps glycerol or another organic solvent—all which will be recycled with rather ordinary technology. [see footnote C] Of these chemicals, only sulfuric acid poses any dangers, but it is much less troublesome than hydrofluoric acid or fluorine gas which have been suggested for use in regolith refining. Sulfuric acid leaching of anorthosite is a preliminary step in aluminum production by electrolysis, so this has already been explored.

The technology is fairly straightforward. A few solar furnaces, electrostatic belt separators, an acid resistant vat and some accessory items are basically all that's used. Plenty of cement, plaster, glass, iron, aluminum alloy and magnesium could result and massive quantities of oxygen will be extracted from simple lunar soil. The Sun can

supply free energy directly to the furnaces and smelting pots without the inefficiency of conversion to electricity and then heat. Even zone refining could be done with solar heat application. Large scale zone refining should be possible in the vacuum and low gravity of the Moon and it may find many new uses there. For these reasons, I believe that this process will be more energy efficient, involve less time and lower temperatures than magma electrolysis and alumina electrolysis. Mere solar reflectors and lenses will be needed rather than large areas covered by photovoltaics and heavy complex electrical equipment.

Other processes have focused on pure silicon and pure aluminum while discarding valuable feedstock for glass, cement and plaster as silicate slag. That's wasteful and dangerous when we consider that silica and calcium constitute over half of the regolith by mass, and that survival on the Moon will depend on efficient use of available resources. Large quantities of cement, glass, plaster and cast basalt will be used to build sub-selene cities in lava tubes someday.

Early lunar bases could be made of steel pressure shells buried under several meters of regolith for radiation shielding and thermal insulation, so the focus at first will be on lunar steel production which is already well thought out. Due to the low gravity of the Moon, over 60 feet of regolith would have to be placed over a concrete shell pressurized to 14.7 psi to keep it in compression. Steel will be the material of choice for the first moonbases. When we find lava tubes or build steel domes the size of football stadiums on the surface of the Moon, we will pour concrete floors, build brick walls, spackle them with plaster, lay down tiles, install plumbing, etc.

Some Notes:

- A. Carbide formation is undesirable as it will remove carbon from the recycling loop. Adding silica to the melt could reduce the carbides. It would also add silicon to the aluminum alloy.
- B. I don't know what the properties of this alloy will be, but silicon, magnesium, manganese and chromium are common aluminum alloy ingredients. Titanium, zirconium (a major regolith trace element at 311 ppm) and vanadium present at 114 ppm are also used in aluminum alloys. Serendipitously, this alloy may have surprisingly good properties.
- C. Carbon monoxide and sulfur dioxide will result during reduction of sulfates and oxides. The CO will be converted to methane and water by reacting it with hydrogen in a Sabatier reactor. Solar heat will be used to pyrolyze methane to recover carbon and hydrogen. Water will be electrolyzed to recover hydrogen and obtain oxygen. This process would have to be used if alumina was reduced electrolytically because the carbon electrodes react with oxygen released from alumina and burn up at the rate of 3/4s ton of carbon per ton of aluminum. Either way you look

at it, we have to process CO to recycle carbon. Sulfur dioxide will be separated from CO by fractional liquefaction, combined with oxygen in the presence of a platinum or vanadium oxide catalyst to get sulfur trioxide which will then react spontaneously with water to reform sulfuric acid. These reactions are highly exothermic. The heat released when regenerating acid can be used to drive electrical turbo-generators for efficiency. < DD >

Author's Footnotes: Works Cited: [1], [2],

[1] see <<http://www.slagcement.org/>>

[2] "Glycerin" Kings American Dispensatory <<http://fddisunsite.oit.unc.edu/herbmed/eclectic/kings/glycerium.html>>

[3] Stephen Gillett. "Organic-based Dissolution of Silicates as an Approach to Element Extraction from Lunar Regolith." Return to the Moon II Proceedings of the 2000 Lunar Development Conference. Space Front Press: 2000. [d]

[4] "Gypsum:" Van Nostrand's Scientific Encyclopedia 8th ed.

[5] See <<http://www.solarpaces.org/SolAl.htm>> and Jean P. Murray. "Solar Production of Aluminum by Direct Reduction of Ore to Aluminum-Silicon Alloy."

<[http://wireO.ises.org/wire/doclibs/SWC1999.nsf/id/5DF399DEE020E9A5CI256920003D617B/\\$File/089.pdf](http://wireO.ises.org/wire/doclibs/SWC1999.nsf/id/5DF399DEE020E9A5CI256920003D617B/$File/089.pdf)>

Editor's notes:

[a] Volatile harvesting need not wait for Helium-3 mining. Volatiles can be scavenged from all regolith handling operations including surface mining, road construction, transformation of regolith into starter agricultural soils, etc. See MMM #23 MAR '89, pp 4-5 "Gas-Scavenger" (online at: www.asi.org/adb/06/09/03/02/023/gas.html and see also MMM #38 SEP '90, p 4 "Primage")

[b] Significant amounts of solar wind-derived carbon will be harvested as byproducts of Helium-3 mining and other regolith handling operations. More carbon may be harvested from carbon oxide ices immixed in lunar polar water ice reserves. While the primary need for carbon will remain the lunar biosphere and food production cycles, some should be available for industry.

[c] That might be so "all else being equal," but all else is not equal. On the lunar surface, pure magnesium which will actually burn in air, will work fine. I expect that magnesium products might gain a bigger percentage of the "work load" on the Moon than they have on Earth. Alloys which need a smaller percentage of exotic (uncommon on the Moon) additions may be cheaper and get the edge when their performance is "good enough."

[d] Stephen Gillett had previously presented a paper on these ideas at ISDC '98 Milwaukee entitled "Molecular Nano-Technology, Space Resources, and the Moon" The ISDC '98 Proceedings have not been published (as of 2003) and this paper is not online. << PK >

“Working Vacations”

An Ideal way for Lunan Pioneers to get a Change of Pace and a Change of Scenery

by Peter Kokh

Not a New Idea

While not common, the idea of spending one's vacation pursuing another line of work, whether just for the change of pace and change of scenery, or to see if one likes the new "job" better than one's current dreary drudge is not new. I've done it more than once to make sure that I wasn't making a big mistake switching jobs. But here we are talking more about working during vacation just for the chance to enjoy new, perhaps even exotic experiences.

Indeed, here we are talking about being willing to *pay for the privilege* of indulging in the temporary job, when that is the only way to get a timely chance. We do not know who was the first to suggest a "working vacation" but these days one can sign up, and pay a registration fee, to go along on an archeological "dig" or man the sails and do other duties on a "Windjammer" cruise aboard an ancient sailing vessel. The organizers get more than free labor, *paying labor!* The eager-to-pay recruits get in exchange, an experience of a lifetime.

Archeological digs can be in prosaic Illinois, or in storied Mongolia. Either way, the work, to the temporary novice, seems exotic and engrossingly interesting. One typically works under a competent university staff capable of answering an endless flow of questions. Not quite Indiana Jones stuff perhaps, but close enough. Recruits willingly pay hundreds of dollars for the chance.

Think of it as tuition, a reasonable fee for a precious learning experience. How is it different from an apprentice paying to work under a master?

Fast Forward to the Moon

Consider these points:

- On any frontier, there is always more work to be done than people to do it, let alone the money to pay them.
- Many endeavors can be pursued at a relaxed pace, *when there is money and people available*
- People need a vacation less to collapse into dormancy than to enjoy a change of pace, a change of scenery, an escape from everyday pressures and work-related problems and irritating persons

On the Moon, we do not currently expect that there will be any archeological expeditions - *unless* we stumble on a hoard of alien artifacts, carefully deposited for us (anyone) to find someday, in a lavatube where they could lie undisturbed by the cosmic elements for millions, even billions of years. But there are other worthy expeditions whose findings may someday improve the life and prospects of lunar settlers:

- prospecting for unusual concentrations of strategic or rare elements
- Exploring Lavatubes
- Building roads or cableways into "new territory"
- Erecting radio telescopes in deep Farside, etc.

Working Volunteer Vacation Programs

A Google search will show that whether you want to dig for fossils or ruins or gold, or help restore a building that has fallen on hard times, or participate in building a timber-frame home or barn, or man the sails of a windjammer - if it means enough to you that you are willing to pay for the experience, you can do it!

Some Examples

www.crossculturalsolutions.org/

Cross-Cultural Solutions is a not-for-profit international volunteer organization that operates volunteer programs in Brazil, China, Costa Rica, Ghana, Guatemala, India, Peru, Russia, Tanzania, and Thailand.

The U.S. tax-deductible program fee for three-weeks is \$2,315 (£1,475), with each additional week of stay only \$220 (£140) per week.

www.voluntarywork.org/go.htm

International Directory of Voluntary Work

www.globalcitizens.org/whoweare.html

"The program cost of \$600-\$1,650 covers in-country travel and lodging, most meals, orientation materials, a share of the team leader's expenses (team leaders are not paid) and a donation to the village project. Airfare is additional. All trip-related expenses are tax-deductible in the U.S.

"Many people ask why they have to pay to volunteer. GCN receives no outside funding or grants and other than two part time staff people is completely volunteer driven. Also, while individuals may be able to travel for less to many of these places, GCN provides the entrance into a village and exposure to a culture that one could not receive if traveling solo to these places. Through the long-term partnerships that GCN has established with communities around the world, volunteers gain a unique perspective into life in a Guatemalan village or on the Navajo Reservation."

www.woof.com.au

Working on an Organic Farm in Australia pays for your room and board while there.

www.parentspress.com/ffdinosaurdigs.html

Dino Digs, guided fossil-hunting for a fee

<http://charityguide.org/charity/vacation/archeology.htm>

Archeology Digs and Restoration Projects

www.robeks.com/Library/Document01.asp?PT=D&PID=68

A general article on the subject.

Lunar Working Vacations Spent Prospecting

Field work prospecting on the Moon will be tedious and monotonous work whether or not most of it is done from within the comfort and safety of a pressurized rover. For that reason, as well as in the interests of thoroughness, accuracy, and timeliness, most lunar prospecting will be done from orbit. But even with great improvements in resolution, orbital surveys risk missing the unusual find.

The surface regolith effectively samples the host crust. There is nothing within the upper kilometer or so of the crust that does not lie exposed on the surface in the debris blanket.

But what about deep mining? What about small nuggets of concentrated elements or minerals that are not widespread enough to show up from space? It is likely that there will be some surface prospecting, whether it is led by university staffs, treasure hunters, or clubs of prospecting enthusiasts. In all of these cases, paying for help will be a problem. But why do that if there is a supply of volunteers who would willingly pay for a 2 week experience?

The ultimate prize for prospectors would be the discovery of a Sudbury*-like "astrobleme" rich in iron, copper, nickel and other elements rare on the Moon, a gift of some impacting asteroid. (*Sudbury is in Ontario, 100 miles east of Sault Ste. Marie.) Such a find would soon lead to a new settlement and much industry. The economic viability of the Moon would receive quite a boost.

Another prize, for drill-prospecting would be the tapping of underground pockets of gases such as carbon monoxide. Such a reserve of carbon would be the lunar equivalent of an oil field, giving rise to a host of new organic chemical industries. Until we find the first such pocket, we can't be sure that any exist. The find of just one would touch off a flurry of additional drilling ventures.

Lunar Working Vacations Spent Exploring – Lavatubes

Again, almost all lunar surface exploration will be more thoroughly, accurately, and quickly done from orbit. But we believe that there is much to explore below the surface, the lunar lavatubes, and possible remote instrumentation is not likely to do more than identify promising areas for on site exploration. The various maria may be laced with these subsurface features, possibly multiple layers of them. Work galore for many generations of volunteer explorers to come. Lavatubes a hundred meters across and many kilometers long are thought to be garden variety.

Some of these ventures will be organized by Luna University Geology Department staff. Other expeditions will be put together by clubs of "tubing" enthusiasts who hope to pay for their own equipment and expenses as well of those of volunteers with the fees paid by volunteers to participate. It will be exciting and promises to be significant. Lavatube networks may someday host industrial parks, warehousing and archiving complexes, lunar agriculture, and spacious lunar settlements.

Lunar Working Vacations Spent in Construction

You may work in the lunar farms, or in materials processing operations, or in a hospital or school, or have a job concerned with exports and imports. Whatever, when it gets to vacation time, you may welcome a chance to roll up your sleeves and spend a few weeks in construction work, "helping to build the Moon."

There will be plenty of teams to join as a paying volunteer. There will be construction of additional housing, of commercial and agricultural facilities, spaceport expansion, highways and cableways. You might even get in on construction of a major Farside radio telescope array.

Lunar Working Vacations Spent Establishing New Outposts

One town does not establish a lunar civilization. A real lunar domestic economy will require some variety of towns, each with their own advantages of location, be they scenic, mineralogical-industrial, logistical or other.

Any number of secondary outposts will also be established. Over time, the vast empty regions "in between" will be filled in. It could be just the shot in the arm you need to spend your vacation helping establish a new outpost in some remote region. And it would not be surprising if you or some of your fellow volunteer pioneers after returning to your regular day job, put in for a permanent transfer to the new outpost.

For Tourists from Earth: Working Cruises

The working vacation is a paradigm that bears consideration in a much earlier era. It is quite possible that before the first human returns to the Lunar surface, tourists will skim above its surface in loop-the-Moon tours, never landing, but getting the visual experience of a lifetime. Perhaps there will be two classes of passengers. Those who are just along for the ride and experience will pay (a) full(er) fare. Those willing to crew the tourist ship itself, becoming cooks, stewards, entertainment organizers, etc. will get a discount (to be made up for by the "fuller" fares of plain passenger-tourists.)

Once a permanent outpost is established on the Moon, costs of expansion can be kept down if interested capable persons pay to belong to the crews involved. After all, the demand to be on the great adventure will be great. Demand creates supply - there will be little need to "hire" pioneers at any level, even the most demanding.

If people pay or partially defray the cost of their own passage and maintenance, then mission costs become largely those of equipment. Yes, it is naive to think that all personnel costs can be reversed in this way. But it is a paradigm worth pursuing and pushing as far as it will go.

If the lunar, Martian, and space frontier in general are anything like frontiers of the past, much of the "front wave" in every aspect of this grand venture can be managed by paying volunteers on work vacations. It wouldn't be the first time.

<MMM>

WORK VACATION CONTRACTORS

EXPLORATION ORGANIZERS

MC TUBERS

Mare Crisium Tubers, LLC. is a Lavatube Exploration Club operating in the southwestern quadrant of the mare. We currently organize six exploration ventures a year. Prospective volunteers must undergo rigorous physical and mental tests. Those who pass are invited to join us.

Venture fees are currently ₣ 3000 Tanstaafls per person. Fees cover equipment rental and amortization, food and supplies, and other venture costs. Veterans of three or more expeditions will be invited to become regular members of the club.

MCT's staff includes faculty members from the University of Luna Geology Department.

To see a video of our activities, simply log on to our website: www.mc-tubers.com.lu

Please feel free to drop in at our Club House at:
32 Arne Saknussem Lane - **344-6666**

PHOTOGRAPHIC EXPEDITIONS

MoonSnaps, LLC

MoonSnaps organizes several photographic sorties each year to craters, rilles, and other moonscape features of special scenic beauty. We have several slots open to paying tourists willing to do support duties. For information on upcoming expeditions, current openings, fees, and how to apply see our website: www.moonsnaps.com.lu

57 Alan Bean Drive #18 - **867-4668**

PROSPECTING EXPEDITIONS

AstroLode Prospectors, LLC

We have a backlog of some 137 "sites of interest" to investigate as possible "Sudbury" astroblemes, formed on impact by metal-rich asteroids, and thus atypically rich in iron, copper, nickel and other strategic elements vital to our growing lunar economy.

Our expedition staff includes faculty from the University of Luna School of Mineralogy & Mines. Two or more expeditions are always in some stage of planning, and we have openings for physically qualified working volunteers. For opportunities, special skills desired, fee schedules and a gallery of photos from recent expeditions, see our website at:

www.astrolode.com.lu

650 University Circle - **783-2879**

REGIONAL CONTRACTORS

LUNA CITY AND NORTHWESTERN CABLEWAY

LCNW is extending its passenger and freight cableway line from Luna City, along the Mare Crisium north coast, and through the highlands into Mare Frigoris and the North Junction Settlement. This work will take us several years to complete. We always have some openings for qualified work vacation volunteers. For a photo gallery, progress updates, information on current work stretches, special talents of interest, and fee schedules, see our website at:

www.lcnw-cableway.com.lu

150-180 Enterprise Road - **222-5227**

GOVERNMENT DEPARTMENTS

Lunar Frontier Republic Dept. of Highways

The DoH has openings for work vacation volunteers on the East Interpolar Highway Project. We are now working on the Mare Humboldtianum-Marginis-Smthii-Austale stretch, laying road in both directions from Mare Marginis. Modest fees scaled to qualifications and expertise. More information online at:

www.doh-luna.gov.lu

- **444-9297**

Lunar Frontier Republic Dept. of Commerce

Office of Transportation Logistics

The DoC-OTL is charged with deploying self-service stations along Frontier Republic class 3 minimally improved trails to enable the establishment of remote outposts. These solar-powered stations can recharge batteries and fuel cells, and provide emergency communications. These modular units include a sheltered garage space equipped with tools to be used on the honor system. Those interested in work vacations in rugged, minimally touched terrain may apply for two week openings. More information online:

www.doc-otl-luna.gov.lu

- **782-8466**

WORK VACATION BROKERS

Bid-4-it.com is a registered broker for dealers and suppliers of goods and services in slack demand situations. On occasion we have work vacation packages available for bidding. You place your price bid, state your availability dates, and give your credit card data. If the provider accepts your bid, it becomes a legal contract. Successful bids of half price and lower are not unheard of. Visit us online at:

www.bid4it.com.lu/workvacations/

Artemis Moonbase™: Correcting Design Flaws in the EVA Module

by Peter Kokh

Last November, as an outreach aid for the Moon Society Milwaukee Outpost, we designed and built a storyboard about the Artemis Moonbase™ [1], and built a scale model of the Moonbase' original Habitat module along with its attached EVA-Hatch-Docking Module[2]. along with a moonscape diorama for it to sit upon [3]. All three display components were designed so as to be easily replicated by others, with complete instructions on the web.

[1] http://nsschapters.org/hub/storyboards/sb_artemismoonbase.htm

[2] http://nsschapters.org/hub/exhibits/artemismoonbase_model.htm

[3] http://nsschapters.org/hub/exhibits/moon_marsscapes.htm

While I used minimally modified off-the-shelf commonly available components, every effort was made to have the finished Moonbase model as like that shown in the Artemis Poster as possible. A photo of the finished product can be seen at:

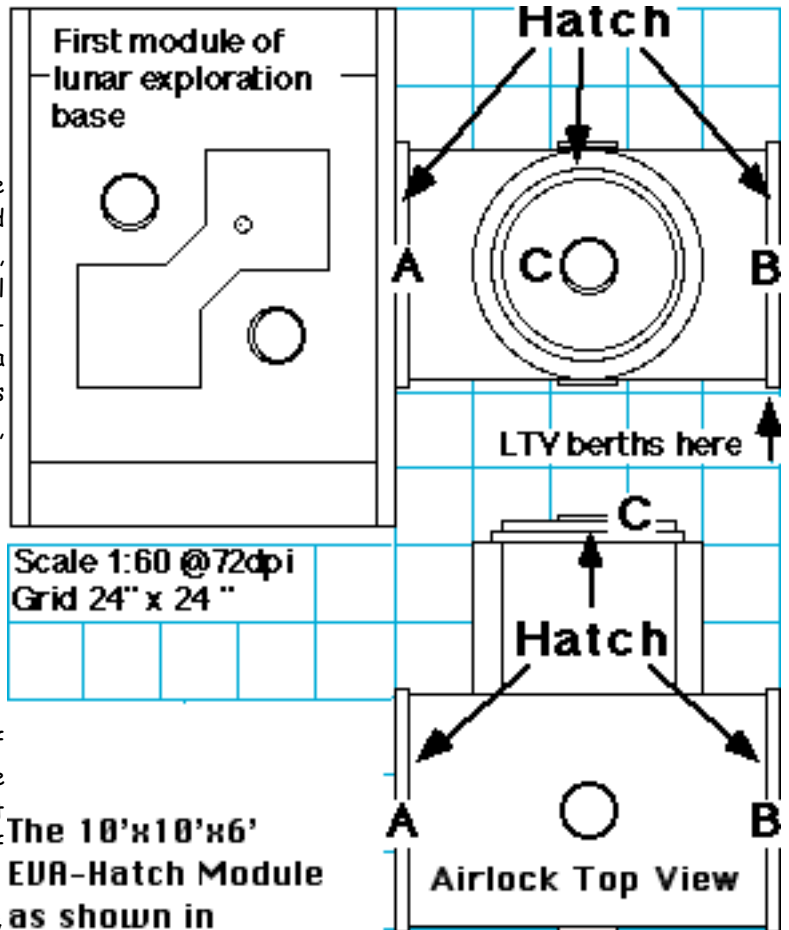
http://nsschapters.org/hub/photos/amb_exhibit.JPG

Design problems noted

It is one thing to design something in your head. The followup exercise of sketching it out on paper often reveals flaws in the original concept that need to be addressed. But that is not the end of the "reality check" process. Building a three-dimensional model often in turn reveals additional problems with the improved design.

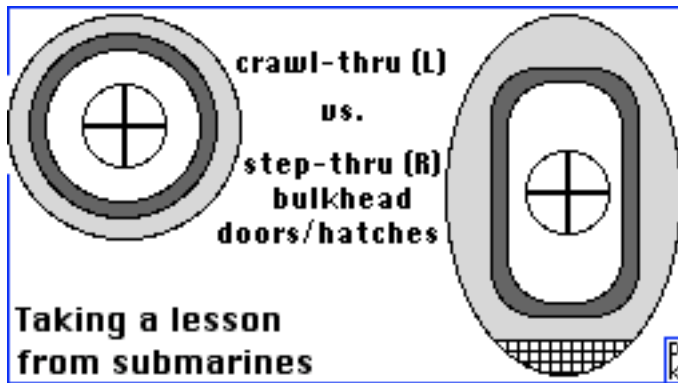
The first thing I noticed is that in the original artwork, the EVA-Hatch-Docking module is cantilevered out from one end of the main habitat module, a triple-ganged SpaceHab unit, without any additional support. Albedo is shown, but that clearly does not provide any support for this massive module. In the model I produced, I added an adjustable foot at the far (right) end of the module. And probably this would not be sufficient. At least a pair of adjustable feet are needed.

But there is a bigger problem with the EVA-Hatch-Docking Port Module itself that does not show up in this modeling exercise. Take a close look at the original design sketches at right. Clearly this module was designed as if attached to a space station module i.e. for a gravity free environment. One "flies" or "swims" through the round hatches to the inside or outside space beyond.



Ease of Function follows Proper Form

Used in a gravity environment, even a reduced one-sixth Earth-normal one, flying or swimming through hatches is out. One would have to crawl through them, a cumbersome exercise that can be tolerated for a short time perhaps, but which will quickly become a major gripe and cause of resentment towards the designers. Even at the penalty of greater weight, and thus of shipping costs from Earth, it would be better to redesign the module in an oval fashion, with vertically elongated hatches that one could "step through" as in WW II submarine bulkhead doors.

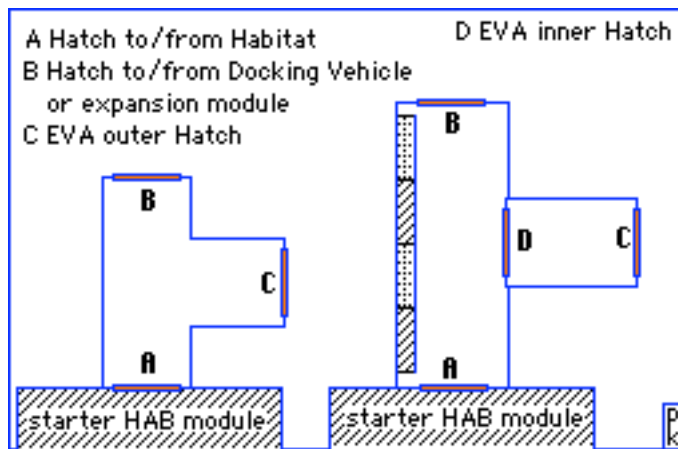


It is essential to realize that this module serves as the "growing point" of the infant outpost. The far end serves as docking point for now, but will soon become the attachment point of an additional, possibly larger module of a design similar to the starter SpaceHab triple module or perhaps something altogether different: say a retrofitted space shuttle external hydrogen tank, or an inflatable sphere or torus.

Either way, if the complex is to serve as one integrated outpost, passage from one part to another should be easy and natural and not laborious and annoying. We don't need this EVA-hatch/docking module to have a "mickey mouse" design. Ergonomics are important for both crew morale and crew productivity.

Second the EVA-Hatch-Docking Module should be designed so that the EVA port can be sealed off from the main passage from the SpaceHab module to whatever is docked at the far end. It's simply a matter of common safety. If that means that the module must be extended in length etc. to provide this isolation, then we must bite the weight and bulk penalty bullet.

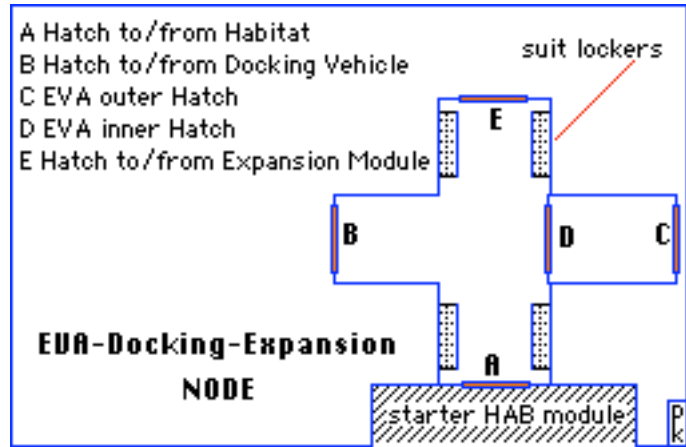
Further, lockers for space suits should be a built-in feature, not an afterthought



But these two improvements are not enough. It is vital if this "connector" or "node" module is to be part of a larger outpost complex that functions well, that one port should not serve both as docking vehicle access and growth module expansion port. Four ports are necessary:

1. access from original module
2. EVA port to surface
3. Docking port for visiting vehicles
4. Expansion port for attaching new module

We will need an X shaped module if the starter habitat module is going to indeed be the start of a larger, fully functional outpost.



We do not need such a node every time we add an expansion module. A third module could connect directly to the second, for example. Until the outpost is much larger, a second EVA port and a second docking port might not be needed to handle the "traffic."

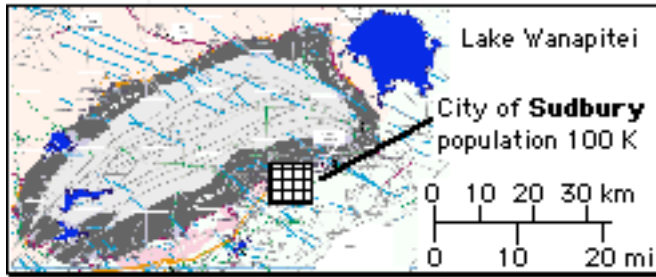
Nonetheless, I would recommend a second such node be added at the far end of the first expansion module, just for safety sake, i.e. backing up one's access to the surface and to incoming vehicles, should the original EVA port or docking port be disabled.

Actually, it would be helpful to develop a whole "language" of modules by which the outpost can develop and expand in an orderly fashion. The various possible modules will be "words" that the outpost decision makers will put together in "expansion sentences" as seem to fit the expansion needs of the moment to provide orderly growth of the outpost and its capacities in just-in-time fashion as outpost activities, crew, and opportunities for economic milestones unfold.

Artemis Project™ Reference Mission:

It is our opinion that the "Reference Mission should remain open, be ever "tentative." I propose that ASI should adopt as a goal to improve the reference mission including optional directions with the purpose of helping prepare the ground for TLRC [The Lunar Resources Company who holds the trademarks on the names "Artemis Moonbase™" and "Artemis Project™"]

Or for whomever can put together the capital and economic plan to make the improved multi-option plan work. < PK >



in FOCUS: On the Road to Sudbury and Lunar Prospector 2

Editorial Essay by Peter Kokh

September 23, 2003, SUDBURY, Ontario, Canada. I find myself tonight, in an RV park just south of Sudbury, on a trip with a friend to the Canadian Maritime Provinces (Nova Scotia, etc.) and New England. I'd first been through this very special town decades ago, long before I knew that it was special. Founded first as a Canadian Pacific railroad hub, it soon became a lumbering center. But underneath lay relics of an ancient visitor, shattered shards that would thrust upon this town, a quite different importance. Nearly two billion years ago, an iron-nickel-copper-rich asteroid 35 cubic miles (146 cu km) in size plowed into what would someday be North America at this location, at mach 100, creating the second largest impact basin on Earth (the much younger 65 million year old dinosaur-killing Chicxulub crater in Yucatan being third largest.) In the intervening 1.85 billion years, nearby mountain building activity, a smaller impact creating the Wanapitei Lake basin along Sudbury's NE edge, and constant erosion have deformed the basin to the point that it can only be recognized from space - but from that perspective, it is quite clear.

Much of our current geological theory results from the examination of this site. Indeed, the Sudbury site and the craters of the Moon have shed light on one another.

The nature of the 9 km (5.5 mi.) wide impacting asteroid that must have erased all life for hundreds of miles around, is the critical point: The Ni-Cu-Co-Pt-Pd-Au (**nickel, copper, cobalt, platinum, palladium, gold**) deposits in the Sudbury footwall are among Earth's most valuable. In 1995, an average 508 tons of nickel and 481 tons of copper were mined per day. A gift from the sky indeed!

The point - The elements listed above, all strategic to modern industry and technology, are precisely those in which the Moon seems to be most deficient. Apollo and Lunakhod rock samples show them to be present only in parts per million (or billion!) concentrations. This fact threatens to hamper the rise of a diversified industrial economy on the Moon, unless Unless the same sort of event has happened there! Now it may not have. The Sudbury impactor was an uncommon one. Most impactors are

stony or stony-iron bodies that have left no such endowment. And while the Moon appears to us as the more heavily cratered, Earth, with its much more powerful gravity well, attracts eight times as many passing bodies into its maw.

Our point is that it may have happened. How deficient the Moon is in these critical elements is unimportant *if*, and that's a big "if," a Sudbury-like event occurred somewhere, *anywhere* on the Moon. We simply have not yet examined the Moon's surface from orbit with instruments *designed to detect* any subtle, telltale signs that any crater was formed by such a metal-rich asteroid.

Question: what instruments could detect this bounty from orbit? We do not presume to know. Remote sensing experts could examine current orbital thematic imaging maps to see if the Sudbury structure shows any anomalous features that trace to the elemental makeup of the impactor. If no such clues show up, that is a sign that no instruments used to date are up to the task.

Then it becomes a problem of brainstorming the instruments designed to detect one or more elements in the Ni-Cu-Co-Pt-Pd-Au group, and putting such an instrument in Earth orbit to verify how well (or if at all) it picks up the Sudbury impact basin, identifying it as rich in these elements. If we succeed, the next agenda item is to put a duplicate instrument on board a follow-up Lunar Prospector probe and fly a thorough mapping mission of the Moon. We may pick up nothing. But the stakes are high. If we do find a lunar Sudbury, even one much smaller in size, the import for the future of the Lunar Economy will be immense.

Discovery of a lunar "Sudbury" would guarantee that site as a candidate for a major industrial settlement. Even if it was a secondary one, in a remote area of the Moon, it would be vital to the lunar economy. If the Moon has to import all the nickel, copper, cobalt, platinum, palladium, and gold needed for its industries, this will have a negative effect on the lunar settlements' ability to achieve a positive trade balance, it's ability to earn enough from exports to pay for needed imports. A positive find would create a wave of optimism about the Moon's future, and enable the frontier to attract much more investment.

Discovery of a Ni-Cu-Co-Pt-Pd-Au-rich "Mother Lode" would be the third post Apollo "find" leading to a major rethinking of the Moon's potential economic import. First was the mid-70s discovery of the fusion fuel Helium-3 in solar wind gases trapped in the regolith powder. Second was the '98 discovery of major hydrogen deposits (water-ice being the simplest, most logical source) in permanently shadowed craters in the Moon's north and south polar regions. With each of these discoveries, the Moon has become much more than the barren rubble pile explored by the Apollo astronauts. Behind door # 1: Helium-3. Behind door #2: water-ice. Our task is to do the orbital Earth-search first, then push for a Lunar Prospector 2. - PK.

Producing OZONE on the Moon for use in Water Purification and as a Rocket Thruster Fuel

by Dave Dietzler < pioneer137@yahoo.com >

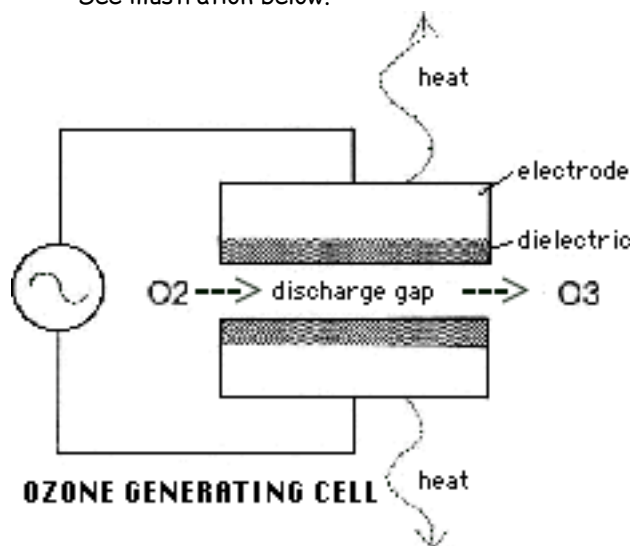
Ozone: O₃, a triatomic form of Oxygen (normally diatomic, O₂), a bluish irritating gas of pungent odor

There isn't much Chlorine on the Moon, but there is plenty of oxygen in the rocks and regolith. Oxygen can easily be converted to ozone with electrically powered ozone generators. Ozone can be used to safely sterilize water supplies more effectively than chlorine does and it is a powerful bleaching agent.

Some thinkers have suggested running water through glass tubes [1] on the lunar surface and letting solar UV rays sterilize water, but this won't work for 14 out of 28 days at most lunar locations. Also, do we really want to risk pumping our precious water through glass tubes that could be shattered by micrometer impacts? Or crack due to thermal stress? Or be easily destroyed by a terrorist with merely a sledgehammer? I feel much better about ozone.

Liquid Ozone is a more powerful oxidizer for rockets than is liquid Oxygen. Unfortunately, liquid Ozone is sensitive to mechanical shock and vibration and can decompose disastrously. Compressed gaseous Ozone won't do this, therefore it could be used for thrusters that burn silane. The use of silane (SiH₄, a silicon analog of methane, CH₄) and gaseous Ozone for thrusters could extend our precious Hydrogen supplies.

See illustration below.



[1] The editor [PK] has frequently suggested using quartz covered tanks for solar ultraviolet purification of waste water. Quartz lets solar UV through unimpeded, whereas glass partially filters UV. An easily changeable sacrificial outer pane of quartz could protect the quartz-lid from the vast bulk of micrometeorite strikes.

Smelting Moondust: a PostScript

from Dave Dietzler < pioneer137@yahoo.com >

In my article in last month's issue [MMM #168] I went out on a limb and yet seem to have been saved by serendipity. I've been fretting about the proportions of lime and SiO₂ (silica, sand, same thing) in the stuff after H₂SO₄ treatment of moondust. It's about 80% SiO₂ and 20% CaO after you break down the CaSO₄ with heat and or carbon+heat. Cement is 65% CaO, 20% SiO₂ and some other stuff. But concrete is made with a 1:2:3 mix of cement: sand: rocks 100 lbs. of cement(contains 60 lbs. CaO)+200 lbs. sand=300 lbs. That makes a 20% CaO and 80% sand mixture. I knew the CaO % was too low for cement but I figured that when you mixed it up for concrete, it would work out and it does.

So what we do on the Moon is take the stuff that we filter out after H₂SO₄ leach of 'de-ironed' regolith, heat it (calcine) at 1400 C. or reduce with carbon to decompose CaSO₄ to CaO (lime), then mix it with an equal amount of rocks (coarse aggregate) and we have concrete. We have to throw in a dash of CaSO₄ also.

After extensive searching, I found out what happens when you mix molten silica with molten CaSO₄. The CaSO₄ breaks down to lime and SO_x bubbles to the surface. They do this to refine glass, but these days they use Na₂SO₄ instead of gypsum. So molten unmixing which seemed so simple won't work. But it doesn't matter, because we can just make concrete! We can get the comparatively small amounts of CaSO₄ just by washing in a 'percolator' or stopping the calcining before all of it breaks down into lime. How do we get the rocks (coarse aggregate)? We sieve all the moondust to catch the rocks because we want the fine dust that will react better in the acid, and get more rocks by chipping away at boulders or blasting. Now if that doesn't work, nothing will.

Summing up with Pictures

Here's help to picture the smelting operation. This page has seven illustrations worth a thousand words each.

www.moonminer.com/Regolith_refining.html

For a follow up summary, also read:

<http://groups.msn.com/DaveDietzler/followup.msnw>

For a flow chart of the whole regolith smelting operation, go to:

<http://groups.msn.com/DaveDietzler/moonmining.msnw?action=ShowPhoto&PhotoID=330>

I'm just an amateur theoretical chemist in need of a laboratory, some witnesses and a video camera to prove my claims, and a US patent. :-)
< DD >

For more of Dave's Brainstorming, explore:

www.moonminer.com



Early Frontier Highways on the Moon

by Peter Kokh

The Moon has a regolith blanketed surface of impact-pulverized rock rubble and powder of variegated graytones. There has been no weathering by wind or water and the pristine impact powder on the Moon remains angular and gritty. There are no rivers, not even dry ones (wadis or arroyos) to cross, no need to provide drainage.

On the other hand, the fact that the momentum of a moving vehicle remains "Earth-normal," its traction is greatly reduced in the Moon's light 1/6th normal gravity, means that extra attention must be paid to banking on curves and/or providing surfaces with enhanced "grip."

The earliest frontier roads; marked trails

Getting down to the nitty gritty bare bones essentials, a road or trail is essentially a route that someone has pioneered and which is visibly evident to anyone who would follow or retrace it. On the Moon, footprints and wheel tracks in the soft, easily compacted moon dust, will remain visible for centuries or more.

The amount of effort to be made in "constructing" a "road" depends on the amount of "traffic" that we anticipate. Clearly, that will change with time. In our own experience, ungraded dirt roads give way to graded ones, then gravel, and finally paved byways.

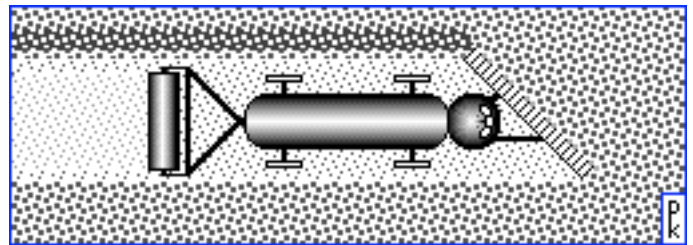
The first outpost may have a number of frequently visited outstations: out-vac tank farms of fuel and other volatiles; warehouses; remote nuclear power station; a launch pad in early stages of becoming a spaceport; a scenic overlook or two; areas of enriched raw materials for early industry, etc. And there will be exploration and prospecting sorties to areas further afield, possibly scouting sites for additional outposts or "industrial parks."

To aid in route surveying and "highroute" corridor designation, we will need more accurate, higher resolution lunar global altimetry maps than those now available. Based on the maps yielded by such a *TopoSat*, potential corridors and routes of varying breadth, both main and tributary branch routes, can be identified prior to decisions on where to site new outposts. Proximity to such routes linking potential sites to the early population centers will be a primary, if not overriding consideration in final site selections. This map of potential traffic routes, color-coded for sections needing special improvement, identifying and quantifying clear-grade and cut-fill hurdles according to difficulty and expensed options will provide one part of a *Global Lunar Development Map*.

Given the Moon's low gravity, grades steep by our own terrestrial standards, may present no big problem, at least not for wide-track vehicles with low center of gravity.

But we'll want to pick paths with gradual changes in grade, and relatively free of large boulders - routes that promise to be relatively easy to negotiate - and which do not lead to dead-ends, e.g. into a box canyon, toward a cliff or escarpment, or into jumbled, chaotic terrain.

The simple passage of other vehicles following a first trail, will compact the moon dust, making the route more clearly visible and easier to follow. But without minimal improvements, average speeds may be rather low. In general, routes will be picked that steer clear of boulders of any size, say a foot (30 cm) or so high. These smaller ones can be handled by the vehicle's suspension but wheeling over them will make for slow going. It will make sense to provide vehicles with a forward, canted rake that will "plow" them to one side. A second parallel pass would widen the "smoothway" to two "lanes." If the "plowing" vehicle has a trailing weighted roller, then smaller rocks of a couple inches (5 cm) or less will be compacted along with the moon dust, making a rut-free smoothway that can be driven at modest speeds. With no additions of extraneous material, the road's color will be that of the host terrain, blending in perfectly. It will show up, from close up or far away, mainly by its clearly "processed texture." The earliest "roadmaking," then, will be a matter of "Rake & Roll."



Trail Smoother rakes/plows small rocks and boulders to one side, leaving pebble size rocks behind, to be packed into soft regolith by the weighted trailing roller. A row of boulders is left to one side. A return pass by the Smoother on the far side of the boulder row, will thicken that row and create a median strip. Boulders in the median strip can be removed where needed to allow left turns onto junction roads. Additional reverse-direction passes to either side of the median would widen the smoothway, and create smaller boulder rows marking the two shoulders. How wide and high would the boulder rows be? That would depend on the amount of boulders in the area smoothed. The boulder rows may be discontinuous, but would still effectively mark the way.

[For a way to trailblaze pioneer roads at no public expense, see *Luna City Yellow Pages*, this issue, page 8, # *Trail Blazers*, LLC.]

"Fixing" the roadway: dust-control

Away from settled areas, dust control, while always helpful (reducing and simplifying vehicle maintenance) will be less important. Depending upon traffic volume, the simple clearing of boulders and modest "smoothing" may

suffice over carefully surveyed routes. But regularly used traffic ways need be more than rut-resistant. They should also be dust-free or dust-stabilized.

Surfaces can be self-paved by fusing or sintering the top layers to a sufficient depth to support expected wheel weights, using microwave beams in a stereo array or focused solar beams in a controlled pattern to produce a hard but not glassy surface, textured to improve traction of spring-tired vehicles. Just how to do this is a matter that will require some amount of determined experimentation, first Earthside with analog materials, then with in-field/onsite confirmation tests with actual lunar produced materials under real travel conditions. Determining cheap and easy pavement options should be a priority "homework" item for the initial outpost-base.

One challenge will be the high surface temperature range of +400° F, +200° C., over the month-long dayspan-nightspan cycle. This will constrain the way and extent to which potential dust-fixers like sulfur are used. "Pavement" strengtheners such as locally produced fiberglass mats may be part of the solution.

As to lunar concrete bear, in mind that this is a sixthweight environment and the "pavement" need not be as strong as that needed to bear up under heavy terrestrial traffic. At the same time, on the early frontier, we can expect a large percent of the traffic to be that of heavy "lith-moving, construction and mining equipment. On Earth, a six to one mix of raw on site soil with cement is enough to produce a serviceable walkway. But will such a low ratio mix sustain construction equipment traffic as well as lighter road traffic? Tests are needed!

Right of Ways and Road/Lane Widths

How wide should a rural highway be? This may seem a strange question. But on the wide open owned-by-nobody Moon, there would seem no reason to arbitrarily limit the width of vehicles, and determine lane widths accordingly. There are no potentially productive lands being eaten up by wider highway rights-of-way. With no air or atmosphere, there is no need for streamlining either. ("dustlining" is another question!) There are as yet no bridges or underpasses or tunnels of set size to influence width and height restrictions. On the other hand, there is low gravity - which brings with it proportionately low traction - along with unreduced full-normal momentum. Together, these conditions make wider than normal track and lower than normal center of gravity, wise design goals. We predict that lunar highways may be generously wide, lane for lane, by our standards.

But roads can always be widened, if the right of way set-aside is appropriately generous. At the very outset, where the traveler does not expect to meet oncoming traffic, one ample lane should be enough. Two ample lanes with a rock median strip, as described above, should do for

quite some time. Eventually populations in various centers, and the trade and passenger traffic between them, may make wider, and even "limited-access" roads advisable.

Graded trails

The simple roadway preparation above, may work well enough for relatively flat mare [pronounce "MAH-ray"] plains of the Moon, the so called seas (actually seas of great lava sheets now long congealed), their upper surfaces reduced to powder and rubble by billions of years of meteorite bombardment and micro meteorite rain - the patchy areas of the Moon that look dark gray to the naked eye. And it is our guess that the first major lunar settlement will be built near a mare/highland coast, probably on the mare itself, for the significant industrial advantage of having access to both aluminum-calcium rich highland soils, and iron-titanium rich mare soils.

But even the maria (plural of mare, Latin for sea, pronounce MAH-ree-ah) are not totally smooth. Successive lava flows have left terminal slopes. Here and there, lavatubes too close to the surface, have collapsed into valleys called rilles, hundreds of meters wide and deep, many kilometers long. Here and there also, more recent major asteroid impacts have cratered the mare surfaces. And in some major impact basins, Mare Smythii being a good example, the subsequent lava floods have been too shallow to bury the older heavily cratered impact basin. The rims of ghost craters poke through the mare surface like so many coral atoll reefs.



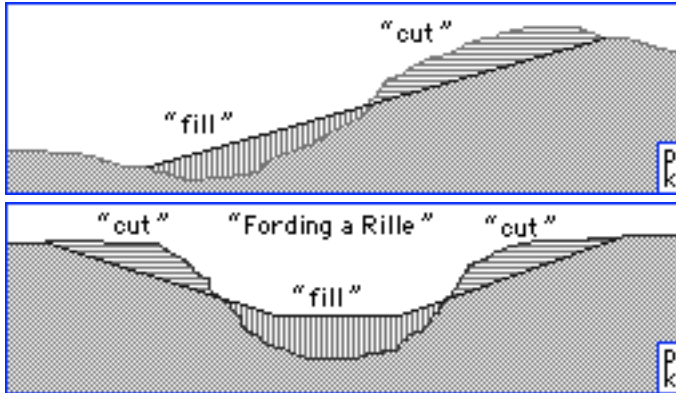
Lighter, crater-pocked highlands surround darker and flatter lava flood plains called maria. The mare, in turn, has several deep rille valleys (left) and flow front escarpments (top) as well as a few younger craters.

And in the highlands, even where reasonably negotiable routes can be found through "inter-crater plains," road making may require more than boulder plow-raking and "smoothing." Aggressive grading may be needed to fashion lanes free enough of small scale dips and mounds to permit acceptable travel speeds. What our Trail Smoother begins, or cannot even touch, will be the job of bulldozers, graders, and other earth moving equipment.

It will be some time before roads outside the peripheries of the settlements are used regularly enough to constitute what we would call "traffic." Only when they do, will substantial grading, paving, and routing improvements to allow higher speeds and shorter trip times become financially justifiable budget priorities.

Forging shortcuts: cut & fill, causeways, bridges, tunnels

These early paths-of-least-resistance routes will do well enough for a start. But as global lunar population and inter-settlement traffic grows, 'shortcuts' demanding extensive "cut and fill" work, perhaps even bridges and tunnels, will become justifiable expenditures. Looking at the sketch above, it is clear that without such engineering, we may have no choice but round-about routes, sometimes a hundred miles or more longer than a direct route. That means more hours spent in transit.



It may be some time before bridges and tunnels are built. "Cut & Fill" is easier, less expensive, low-tech: ideal for a small population with limited industry. The lunar surface is bulldozable down to a depth of 2-5 meters, 6-16 feet. Below that lies fractured bedrock. So major "cuts" will need the assistance of dynamite or other explosives.

Scenic Highroutes

On Earth, "scenic" roads often hug terrain features such as valleys, shorelines, ridges and mountain crests. On the Moon, it will be no different. Routes chosen for the views they afford will wind along rille tops or bottoms, crater rims, and mare coastal ramparts, lava flow fronts etc. As they may well be more expensive to build, such roads will come later, multiplying step by step as the domestic and *foreign* (terrestrial) tourist traffic increases.

Automated Self-Serve Roadside Service Pods

For travel off the beaten path, we must use self-contained vehicles that need no resupply other than what is obtainable from the surroundings. Range will be limited. But along improved roads open to routine travel, wherever the distances between settlements and outposts are substantial, safety and convenience will be promoted by the placement of automated solar-powered service stations.

At such "pit-stops," vehicles can pull up and hook up to refuel or recharge. The station's solar power units will recharge exhausted batteries, electrolyze water from fuel cell operation to make hydrogen and oxygen for refueling other fuel cells. And there will be on site solar power storage for limited nightspan operation.

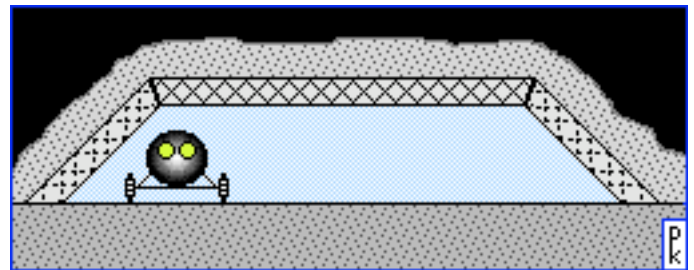
First aid supplies may complement emergency food rations. An antenna for high gain communications is likely to be available.

There may be a locked storeroom stocked with commonly needed parts and tools, accessible by credit card. Use a tool and don't return it, and you get charged not only the purchase cost of the item, but the cost of restocking it to the location at which it was "checked out."

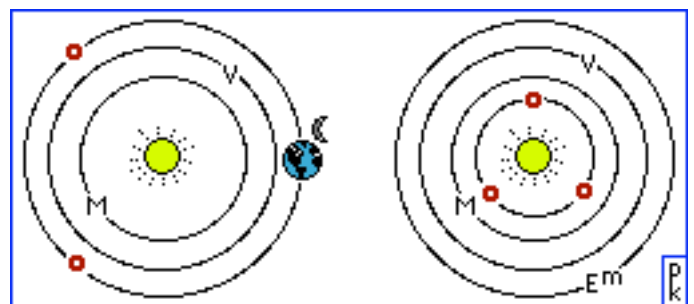
A computer in the main town could keep track of vended inventories and the quantities of water, hydrogen, oxygen, stored power reserves etc. This will allow scheduled just-in-time resupply and equipment maintenance.

Such Stations can be designed as compact units with modular pull-out/plug-in changeable components. They would be trucked to the site, following road-blazing crews, or in advance by all-terrain scout vehicles.

Next in priority will be "flare sheds," covered hangers where vehicles can find shelter from the occasional solar flare. Those readers who had the luck to see the made-for-TV Disney-ABC science fiction film "Plymouth" (shown only twice, Memorial Day Weekend in 1991 and '92) will appreciate the importance of such sanctuaries from the powerful radiation of solar flares.



As advance warning time for solar flares is rather minimal, these havens need to be placed at "reachable" intervals along regularly traveled routes. It will be a high priority for the safety of lunar pioneers to agitate for early placement of flare-warning stations in orbit around the Sun. A minimum of two 120° ahead and behind the Earth-Moon system in the Earth's orbit around the Sun will do. Three, at 120° intervals in a close-in, within the orbit of Mercury, might be better. These orbiting satellites will be able to see around the flanks of the Sun to spot troublesome sunspots before they are carried by the Sun's position to the field of view visible from Earth or the Moon.



LEFT: A two satellite system in Earth orbit covers parts of Sun out-of-view of Earth & Moon to give complete advance warning. RIGHT: three satellites cover the solar globe at higher resolution, from an orbit inside Mercury.

A complete network would monitor developing

storms anywhere on the Sun's surface. With such advanced warning, flare sheds could be placed at greater intervals.

Such sheds can be designed and erected in modular fashion, to grow in shelter capacity as road traffic warrants. In time, some of these refuges may become the nuclei of staffed service centers, including restaurants, lodging, and even recreational facilities.

Motoring on the Moon will be a very different experience for those accustomed to road travel on Earth. Here, even in remote areas from from the roadside spam of non-point-of-interest billboards, even in the most arid of desert and mountain areas free of vegetation, we enjoy conditions not to be found on the Moon. Without water-vapor laden air, lunar skies will be black, even when the glare of sunlit moonscapes is intense. A passing truck will be scarcely noticed, with no telltale "suction" effect as it passes. Vehicles will have to be fully pressurized and more dependable, with backup systems. Without air and wind, awnings against the solar glare will cause no drag.

Properly routed, with scenic overlooks and opportunistically placed waysides (replete with sculpture gardens) lunar highways need not be boring. Yet, to the same people who on Earth feel that "when you've seen one mountain (river/waterfall/lake/cliff/valley) you've seen them all" the Moon will be especially boring. To those of us capable of sensing and appreciating the differences and who marvel and are awestruck by the endless variety, there will be no shortage of scenes full of wonder.

Early highway passenger vehicles will be more akin to our "coaches" or "greyhounds", not in shape or size, but in function. Personal and private vehicles will be available on pressurized in-settlement streets, long before they become affordable or common out on the surface., When they are built, they may be mainly rental vehicles. Few pioneers will need personal transportation between settlements until the population grows substantially, and the economy has diversified considerably. <MMM>

Relevant articles from these past issues of MMM

- # 37 JUL '90, "Flare Sheds" pp. 4-5
- # 79 October 1994
 - p 13. Lunar Roads
 - p 16. Lunar Vehicle Design Constraints
- # 81 December 1994
 - p 3 Rural Luna: Surface Vehicles & Transportation
 - p 4. Over the Road Long Distance Trucking Rigs
 - p 5. Toadmobile Conversions
 - p 6. Beyond the Beaten Path: Skimmers
 - p 7. Spider (vehicles); Camping Under the Stars
- # 82 February 1995 p 7. Rural Luna: The Beaten Path
- # 85 May '95 p 7. Waysides; Farms; p 8. Mines
- # 86 June '95, p 7. Science outposts; Recluse outposts



**Home on the Moon:
Living on a Space Frontier
by Marianne J. Dyson**

Former NASA Mission Controller and Winner of the 1999 Golden Kite Award for best Science Book for Children
Published 2003 by National Geographic, Washington DC
ISBN 0-7922-7193-9. 64 pages, for ages 8-12, \$18.95 retail. For more information, contact: mjdyson@swbell.com

Reviewed by Peter Kokh

This is not the first children's book about the Moon. I have bought others, and been disappointed. The writer always got the "facts" right. But "just the facts," without the possibilities, become half truths giving distorted impressions. Yes, the Moon is airless. So? Yes the Moon has no liquid water. So? When you know all the facts, and the real possibilities, such trivia bits become irrelevant.

Dyson clearly shows the young reader how, with the help of technology, human resourcefulness, and the Moon's own resources, we can live full and exciting lives on this frontier world. Written in large print and plain English to be easily understood by today's middle schoolers ("ages 8-12"), Home on the Moon takes the reader back to the first Apollo/Saturn V Moon mission, then to the letdown years since. With technology developed in the interim, the price tag for lunar outposts now seems much lower. Living on the Moon seems much less dangerous. We now know the Moon has water-ice. We know how to recycle precious elements in agricultural and human wastes, how to provide a radiation-proof blanket of moondust over our habitats, how to make useful metal alloys, and other practical building materials out of the elements common in the soil. The author talks about the Moon's origin and how it got to be the way it is; about its resources, and where they are to be found.

The illustrations are clear, well chosen, and easy to understand for the young reader. "Activity experiments" are included (e.g. demonstrating how a crater is formed; making simulated moon rock from edible ingredients.) The reader learns how pioneers will produce metals, air, water.

Dyson explains how transportation costs will come down, how the early outposts may be built, and how pioneers will get from here to there. She also shows how pioneers will have fun doing things impossible in our heavy gravity, like human-powered flight. The book includes a glossary.

If you have kids, grandkids, or nieces and nephews in, or soon to be in this age bracket, get the book. If you do not, get it anyway and donate it to a school or library. We need to get the word out about the livable Moon! Hats off to Marianne Dyson for an excellent contribution. <PK>

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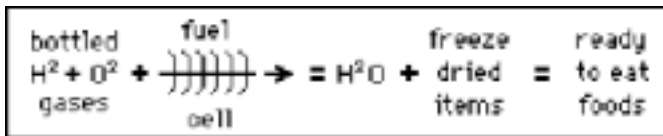
(Lunar) Food is Mostly (Lunar) Water

by Dave Dietzler < pioneer137@yahoo.com >
and Peter Kokh < kokhmmm@aol.com >

Food is mostly water!* [<http://waltonfeed.com/> see table at left.] We can supplement the diets of early pioneers by sending them everything they can't provide in the early salad stuff cabinet gardens in dehydrated form, to be rehydrated with water produced on the Moon from lunar oxygen (from the rocks) and hydrogen (scavenged from the solar wind gases adsorbed to the fine dust particles in the upper regolith layers).

* For confirmation, check the labels on freeze-dried foods packed for campers at your local outfitters supply store. You will be surprised to see that water accounts for as much as 65-80% of the weight of ready-to-eat meals. That's real savings! Backpackers *travel light!*

Shipping supplemental food items in this weight-trimming way makes economic sense when, pending major "Cheap Access to Space" transportation cost breakthroughs, anything shipped to the Moon will cost more than its weight in gold! We already freeze-dry most foods to be used space, *saving all the weight of the associated water.* To rehydrate the food, we use water manufactured in space as a byproduct of the orbiter chemical fuel cell energy system which runs on hydrogen and oxygen. On the Moon we will be able someday to use locally produced water.



But just how tasty are rehydrated foods? This is important, because not only nutrition is at stake. Morale is the one single thing that has the power to make or break any effort to establish human communities on the Moon with any real permanence. Puff-dried foods (some familiar breakfast cereals) seem to perform better in the taste department. But this process is not applicable to all foods, and has the great disadvantage of very low density, taking up too much space in a cargo hold.

Calling entrepreneurs

If this topic interests you, make a trip to your local camping supply store, and purchase a few samples of freeze-dried prepared entrees and side dishes. Campers and backpackers are a hardy lot. What they may be willing to put up with for short durations may not sit well in the stomachs of future frontier pioneers on long or indefinite tours of duty, If you can figure out how to produce more palatable results, there will be enough of a market among choosier terrestrial campers and backpackers to earn you good profits in reward for your labors. <MMM>

Water Content of Some Common Foods 1

[NOTE: Water Content of Foods Dry seeds, such as the grains and legumes were intentionally left off the following list as they should have a common moisture content of 10% or less. All pure fats and oils contain no water. The water content of each of the foods below is shown by the number following the food. After these foods have been dehydrated, their weight will be reduced by close to the following percentage:]

VEGETABLES & SALAD STUFFS

Bean Sprouts	92%	Broccoli	91%
Cabbage Raw	92%	Carrots Raw	88%
Cauliflower Raw	91%	Celery	94%
Collards boiled	91%	Corn Sweet Fresh	74%
Cucumbers Raw	96%	Eggplant Raw	92%
Kale	87%	Lettuce Head	96%
Okra Boiled	91%	Olives	80%
Onions	89%	Parsley Raw	86%
Peas Raw	81%	Peppers Green	9
Pickles Dill	93%	Radishes Raw	95%
Rutabagas Boiled	90%	Sauerkraut Can	93%
Spinach Raw	92%	Squash Boiled	9
Swiss Chard	94%	Tomatoes Raw	93%
Watercress Raw	90%		

FRUITS

Apples	85%	Apricots	85%
Bananas	76%	Cantaloupe	91%
Cherries raw	80%	Coconut Dried	
Fruit Cocktail	80%	Grapefruit Raw	88%
Grapes	82%	Oranges	86%
Pappas Raw	89%	Peaches Raw	90%
Pears Raw	82%	Pineapple Raw	85%
Plums Raw	87%	Pumkin Canned	90%
Raspberries	81%	Strawberries Raw	90%
Watermelon	93%		

CARBOHYDRATES

Bread Whole Wheat	35%		
Potatoes Raw	85%	Pasta Cooked	7
Sweet Potatoes Boiled in Skin			71%

NUTS & SWEETS

Almonds	7%	Pecans	7%
Peanuts Shelled	Trace	Peanut Butter	Trace
Walnuts	%%	Honey	15%
Jams/Preserves	30%	Molasses	25%

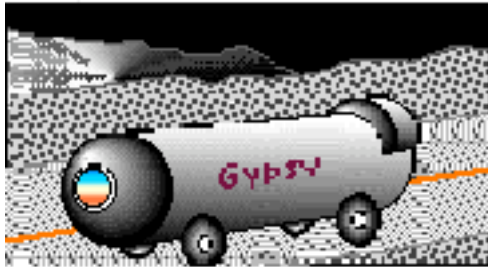
MEATS

Beef Raw Hamburger	54%	Chicken Broiled	71%
Ham Smoked Cooked		54%	Pork Chops Broiled
Turkey Roasted	62%	Veal Broiled	6

MISCELLANEOUS

Butter	20%	Cheese American	37%
Eggs Raw Whole	74%	Margarine	20%

Reference: Nutrition and Physical Fitness 9th Edition by L. Jean Bogert Ph.D., George M. Briggs, Ph.D. and Doris Howes Calloway, Ph.D., W.B. Saunders Company, Philadelphia PA ISBN 0-7216-1817-0, compiled from Table 2A, Nutritive Values of Foods in Average Servings or Common Measures



Pursuing Nomadic Lifestyles on the Lunar Frontier

by Peter Kokh < kokhmmm@aol.com >

We've talked an lot about lunar homesteads and lunar settlements in the past seventeen years of MMM. And indeed, the goal of most pioneers who leave Earth for the Moon and wherever else, will be to settle down in a place that they can call home for a long time, if not indefinitely. Yet we know from our own experience here on Earth that not everyone ends up in a home of their own.

Many persons prefer not to set down serious roots, even after establishing a family, choosing to rent here and there as fits their mood or changing job situations or finances. Surely there will be home rental and apartment type living on the Moon and elsewhere. But in this essay, we want to speak to a less common need, but one which will certainly be part of settlement life for some.

There are people whose jobs or occupations by their very nature requires a highly mobile, sometimes even nomadic lifestyle. One example is the expert whose rare talent is needed now here, now there. He or she may be a mining consultant, an architect, a corporate organizer -- you get the idea. We are not talking about people who are here one week, there the next, but those whose services may be needed here one year, there for the next six months, and so on. They will hardly be happy living out of hotel rooms, never sleeping in a bed of their own. Yes, what we now call "residence hotels" will be an option: quarters that you can settle into, somewhat, with some leeway in superficial customizing being allowed. Perhaps that solution may do well for most of these mobile persons.

But some may want to have their own homes and a permanent home to come home to between stints won't do. They want real homes that they can take them along with them as they move around to wherever business and life takes them. Yes, some analog of what we call mobile homes, motor homes, houseboats, etc. That is the life style we want to explore on the Moon, and those are the analog solutions such people have found workable on Earth.

Various Mobile Habitat Analogs

We are familiar with various types of mobile habitation. Most mobile is today's motorhome, able to go anywhere there are roads, fully self-contained, on wheels with its own engine. Less mobile are trailered and "5th wheel" homes and campers. Next there is a category which has undergone major evolution over the years: the old pick-up-and-go "house trailer" was replaced with the "mobile home"

that generally made but one journey, from factory to a fairly permanent "trailer park" site. This has evolved further into manufactured modular housing.

We'll certainly see a lot of the later on the Moon and Mars. In fact, we think manufactured modular housing will be overwhelmingly predominant. It ensures quality and safety performance, minimizes the amount of time spent by workers in space suits, and is best adapted to meet the needs of a quickly expanding population.

But it is the previously mentioned mobile habitats that are in the range of our topic, and we'll probably see analogs of all of them on the space frontier, along with one other, the house boat and the bargeable floating home. There will be such a variety for two basic reasons: to fit different situations such as expected frequency of relocation, from constant to seasonal to seldom; they need to fit the lifestyle needs and quality expectations of people with different tastes and budgets.

On Earth, many of the larger motorhomes keep personal, smaller, more maneuverable vehicles in tow, much as their waterborne equivalents are equipped with dinghies. We'll probably see something similar on the Moon, but in two basic forms: a small electric cart (think golf cart) for use in pressurized piers and likely-adjacent settlement passages; a fully pressurized out-vac rover. For scarcely mobile lunar habitats on the analogy of floating homes (Seattle's Lake Union, Sausalito) there will be contractors to move them to new sites for a fee.

Mobility Constraints

On Earth, such movable residences must meet certain design constraints to fit the medium in which they are mobile: motor/trailer homes can only be so wide to avoid "wide-load" restraints and only so tall to slip under most bridges; houseboats, bargeboats and floating homes can be limited to where they are able to (re)locate by canal widths, lock widths, fixed bridge heights, etc. Will analogous, if more generous, constraints affect mobile homestead design on the Moon? If there standard clearance height is adopted for roadside solar flare shed shelters, and for "service station garage repair bays" these standards will tend to limit height / width. Road overpass clearances may be in line with those of flare sheds and service bays.

Mobile lunar residences will be built in all sizes, as they are on Earth - from minivan to Greyhound Bus conversions. Customer families will come in all sizes and incomes.

Marina, RV Campground Analogs

On Earth, movable residences are self-sufficient, to a point, but for long-term use need specially equipped parking or docking spaces with utility hookups as a complement. What will the lunar analog of an RV campground, a trailer park, or a houseboat marina be like? Marina/RV parks may impose set size limits, chosen to cater to most common vehicles.

Common Marina Services include: general store (groceries, miscellaneous parts and supplies); utility hookups (electricity, water, waste treatment & CELSS regeneration, cablevision); mailboxes & general delivery, fuels, commons complex (recreational/social activities); transit interface.

Deluxe marinas could offer much more. Attached to the docking portal could be additional enclosed "elbow room" space for the usage of one's choice -- for rent or lease, of course. Assuming that the dock portals all open on a pressurized pier or lane, a deck-porch area for socializing with passersby could be included. Taxi service could be provided for larger units that cannot dock directly but park at some distance at outlying utility hookup spots.

One particular service will be in high demand. A habitat may be designed to perform primary treatment of human waste water (before the effluent passes into settlement systems). It will be impractical for a mobile habitat to provide complete treatment. The marina could accept pretreated waste water in exchange for fresh water as a standard utility service. The marina would also maintain a list of reputable local contractors to meet all the servicing needs of their guests from CELSS systems to power and communications systems and more.

Such marinas could be designed and assembled in modular fashion so that they can grow with demand. To serve as movable "construction camps" a bare bones dock and pier complex could be designed of inflatable elements to be erected in the shelter of a shielded hanger / ramada. These would be especially useful for construction sites sufficiently remote from the main settlement(s) as to make worker commuting difficult.

Shielding: tortoise or hermit crab?

For any kind of frequently roving or infrequently relocated lunar frontier habitat, the question of shielding arises. On Earth our all-blanketing atmosphere provides protection from cosmic rays, solar flares, and micro-meteorites. On the Moon, we'll need a blanket of regolith or its equivalent in shielding protection.

For infrequently moved habitats, more on the analogy of mobile or floating homes, regolith shielding in place seems the logical choice. If sandbagged, this blanket could be easily removed if the need to relocate arises. For mobile habitats regularly or seasonally on the go, the hermit crab has a suggestion: borrow your shielding. Marinas can provide expansive full-shielded hangers for protecting all the vehicles docked at its pressurized piers.

But what can we provide for those who want to park in the out-vac wilds, far from any kind of marina or RV campground type facility? Presumably, they will carry a healthy reserve of water, complete with water recycling systems. While on the road, reserve water can be kept in tanks in the floor of the vehicle, to minimize the height of the center of gravity so as to maximize stability. When parked, both reserve potable water and reserve water in

process of treatment, could be pumped to roof and side-mount tanks to intercept incoming radiation. A thin sheet of metal held in place 6" or 15 cm out from the tanks would safely intercept most micro-meteorites that could puncture the tanks. Interior baffles and automatic sphincters would minimize losses should a rare breach occur.

An alternative, for those who expect to camp in one spot for a week or so, would be a portable ramada or hanger. A folding fiberglass fabric over glass-composite or aluminum tubing framework could travel rolled up like an awning, be automatically deployed on reaching a parking site, and covered with blown on regolith with a remotely steered and operated "blower." The trick is to design such a gizmo so that the shielding regolith can easily be dumped or shaken off when its time to break camp. We welcome reader designs. Send yours to kokhmmm@aol.com!

Road culture & the gypsy, vagabond, nomadic spirit

Here at home, there have arisen a whole suite of subcultures among those who RV/camp frequently, among over-the-road truckers, among those who live in mobile home parks, among those whose occupation has them always on the move, and among those who are nomadic by cultural descent such as gypsies. In the early days of the lunar frontier, when population is small, there may not be a critical mass of like-situated persons-on-the-move to support development of subcultures. But as population grows, we're sure to see some of this.

Such subcultures may have their own music and song genres, their own figures of SEP, characteristic pronunciations, special terms and jargon, their own myths and collections of proverbs, and even in some cases, favored fashion and furnishing styles. It is even possible that these people-on-the-go will become a distinct political constituency. And why not have a legislative representative-at-large to address their concerns?

Cultural diversity and a wide selection of lifestyle choices. Only a small percentage of settlers will adopt mobile living patterns, but their contribution to a healthy, high morale settlement population will be high. <MMM>

[As a boy in the late 40s and early 50s, the author dreamt of owning a "house trailer," and in 1969 bought a used 8x35 trailer of '55 vintage and plunked it down on a rural plot in Northern Wisconsin where it has served as his country getaway for some 34 years now. Conventional construction addition of an extra bedroom and separate dining area were added 6 years later.

In 2003, thanks to a fellow retiree travel companion and his 22 foot Winnebago Rialta, he has gotten to experience "RVing" and RV Park life. He also has had a lifelong fascination with houseboats, and recently visited the major houseboat community in Lake Union in the heart of Seattle. He also has some limited familiarity with cabin sailboats and boating marinas.]

LUNA CITY YELLOW PAGES

EDITOR'S NOTE: When rendering web addresses for lunar enterprises, we have been using the domain extension **.Ju** for **Luna**. It has come to our attention that this extension is taken (= **Luxembourg**) as is **.Ja** (= **Laos**.) The Greek name. Selene suggests **.se** but that extension taken (= **Sweden**) as well. The only option, pending an international agreement on a convention for extending the Internet to other bodies in the Solar System, is the unused extension **.Jn**, i.e. **Luna**, so we will now begin using this. - PK

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Finding "Sudburys" on the Moon

10/12/03 - Peter, you wrote in MMM 169, pp. 1-2

"And while the Moon appears to us as the more heavily cratered, Earth, with its much more powerful gravity well, attracts eight times as many passing bodies into its maw. ...

True, and the Earth could yank them right into the Moon also, could it not? If the Moon were all alone, the chance of a Sudbury impact would be low, but the Earth's superior gravity makes such an impact even more likely because it attracts so many bodies "into its maw." And how many Cu-Ni-Co-Pt-Pd-Au rich asteroids have disappeared into the oceans? How many smaller but rich impacts have been erased by erosion and other geological processes? We do not know. If SMART-1 confirms the ice, we have to urge a search for these Cu-Ni-etc. rich impacts, along with some lava tube searches and mapping. Now, what about a kerogen rich carbonaceous impact? The kerogen would probably vaporize I guess.

Dave Dietzler < Dietz37@msn.com >

Only Private Enterprise will get us to the Moon

In reply to [remark made on artemis-list]: "There is no profit in going to the Moon, so anything sent to the Moon will be an expense for people on Earth. It's obvious that people here don't want to spend money now on space exploration. So I'm thinking any money spent on getting pounds to the Moon should be spent on material that will jump start an economy there."

I just wanted to make a minor nit here. Publicly funded lunar bases just aren't going to happen any time in the foreseeable future. NASA and ESA are all tied up for the next decade or two with ISS obligations. Not to mention all the money they plan on using to keep running the shuttle, develop the OSP, etc., etc. Basically, the soonest they'd have money to even start pursuing such a goal would likely be 20 years from now. So, IMO, even if they were still competent enough to do such a project, I feel Publicly Funded projects can be ruled out.

That really only leaves privately funded projects. While a rich investor might be able to fund such a thing out of pocket, for kicks and grins, that isn't very likely. If we go back to the moon, there must be some potential of making profits (or we must reduce the cost of going to the moon to the point that getting a mission funded without profit motive could be funded). I think that there are several potentially useful markets, such as shipping LOX to LEO for transfer stages, life support, etc. Also, as various metals become available (as per what Peter Kokh was talking about), some of those could be sent as the frames for on-

orbit assembled sat farms, space hotels, etc. If done wisely, incrementally, and quickly, there *can* be a market for lunar products (even more so if we strike a gas pocket, PGM crater, or something else of interest).

Autarchy just really doesn't work in the real world. Obviously with the cost of shipping, the market will favor a lot more self-sufficiency, but some interplanetary division of labor is going to be necessary, even in the long run.

The best way IMO is through the market. If you provide a service someone wants, it becomes much easier to get them to pay you. Trying to get donations from hundreds of thousands of people with no expectation of return is not likely to happen (once again IMO). However, getting thousands of people to buy a product is far more likely. Which is why I think commercial approaches are superior for large capital projects to clubs and charitable donations.

Companies in other industries routinely get millions of people to give them chunks of money (in return for some good or service). I think your approach may work just fine for smaller projects, but once you get past needing about \$50-100k, I think you'll be far better off using normal business practices. Anyhow, that's just my 2¢.

~Jonathan Goff

On early lunar roads -- or railroads!

Dear MMM: I'm now up to my third copy of MMM, and I am blown away! I was especially taken by the items that Peter Kokh wrote about, around building early lunar habitats and highways. These have got my brain spinning off in an interesting direction: designing a first lunar railroad. As a long time rail fan and model railroader, I believe that a lunar railroad would offer some distinct advantages to an early settlement, with benefits often well exceeding highways.

[Lunar railroads] will not be as "dirty" -- Regolith is deeply dusty, so that I don't go along with the idea of "highway building" as described in Peter's articles. Building a highway roadbed would seem to take a lot of work before it's clean, and you would need Kim Stanley Robinson kinds of machines to do the work. A rail bed would get the traffic up out of the dirt, and could be put together by a couple of guys in their spare time.

Railroads were the first real "rapid transit". The Old West frontier basically ended with the completion of the first transcontinental railroad, and the ability to quickly bring quantities of goods and people anywhere. It is not beyond imagination for this to apply to the lunar frontier as well. I would look forward to the joining of rails between the first two lunar colonies.

Bob Wilcox < ramgwilcox@earthlink.net >

EDITOR: I am a RR buff also, and Lunar RRs will be part of the transport mix -- "part." Dust can be managed. - PK-

MMM CLASSIC #17