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

Moon Miners' Manifesto

& The Moon Society Journal

www.MoonMinersManifesto.com

MMM Classics | Year 21: MMM's # 201-210 | DEC 2006 – NOV 2007

In our 21st year, we revisited some of our favorite themes and introduced new concepts.

MODULAR BIOSPHERICS – We continued a series of articles on how biological life support should be tackled in modular fashion, so that as the physical complex grows, its "mini-biosphere" would grow with it, minimizing the problem for centralized facilities.

THE TRIWAY TO SPACE– We attempted to show how the seemingly disparate space-advocacy communities: Moon, Mars, Asteroids, logically fit together in one big puzzle to ensure the survival of humanity and of our home planet.

MERCURY – Here is a planet that is not only hot and hard to get to, but one with unsuspected potential and sure, someday, to support human outposts. This is not as outrageous as it seems!

LEE-VACUUM SPORTS – The great lunar outdoors, or Out-Vac, as we call it, is exposed to the hazards of Cosmic Weather, radiation, micrometeorites, etc. How can we enjoy sports and other activities in lunar gravity without air resistance? The right kind of arena and right kind of pressure suits will help.

THINKING OUTSIDE THE MASS-FRACTION BOX – We began a series of articles attempting to brain-storm our way out of a box created by unnecessary assumption.

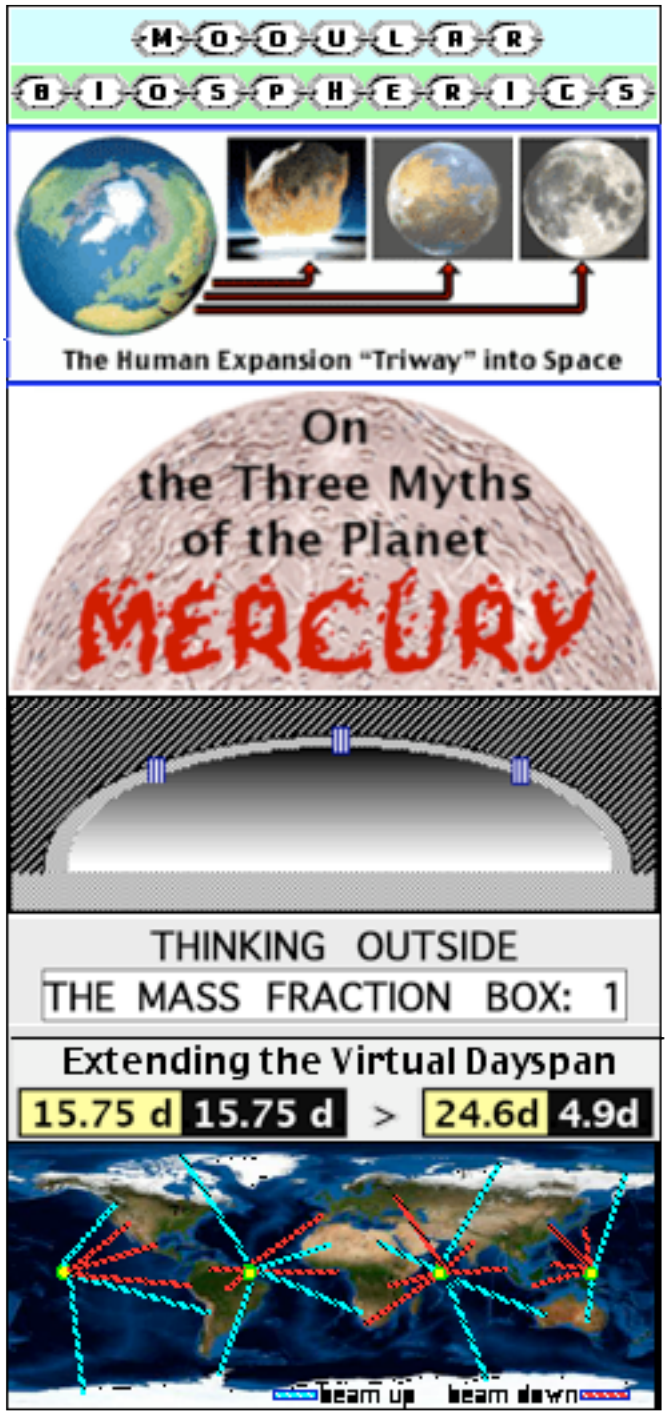
VIRTUAL EXTENSION OF LUNAR DAYSPAN – We suggest a way to provide full dayspan power for a much greater proportion of the lunar Sunth.

A WORLDWIDE ORBITAL GRID – This is an easier sell to a power-hungry world, but far from being an alternative to Space-Based Solar Power, it is the logical foundation for such a system.

OTHER TOPICS – As usual, our March issue was dedicated to Mars, as is only natural, given that a Lunar frontier economy stands to be more viable if it is a trading partner with a Mars frontier economy

Many other topics are treated, some for the first time, some revisited. We try to give the readers an upbeat mix that covers a Solar System full of interests, without being overly technical.

Thanks for your patronage and support.



20th Anniversary Issue

After 10 issues a year for 20 years, it's a "Go" to keep on writing!

By Peter Kokh

A Tale of Two Origins:

I: The Moon as a Challenge

In the late 1970's the editor was already a life member of the National Space Institute, since 1974, and of the L5 Society, since 1977 0r 78. I decided that I would try to write an alternative history novel of "where we could be now (then) if we had not retreated from the Moon with the liftoff of the Apollo 17 Challenger LEM on December 17, 1992.

Surely, I thought, we'd be on Mars or headed that way. Believe it or not, I was a "Mars man" back then. But we'd had have to have "done the Moon" first. So I began trying to figure out how we would "do the Moon." Here we have what appears to be a round rubble pile, lacking in many elements we are used to having in great abundance, not just as traces. I became hooked by the challenge.

That the Moon is deficient in key elements is not an issue. I began to see the Moon as the Japan of the solar system -- Japan, at the start of the Industrial Age found itself in a similar position. It turns out that natural resources are not the key. Human resources of creativity, resourcefullness, enterprise and determination are!

I began to brainstorm how we would substitute for wood, paper, plastics, and many other things. I was soon thoroughly hooked on the "Lunar Challenge."

This brainstorming soon gave birth to a deep conviction that pioneers would learn to make themselves "at home on the Moon" and be able to support a growing economy based first on local import-substitutes and on exports to a growing off-Earth economy including facilities in Low Earth Orbit: research, industrial, and tourist installations in the "suborbs" of Earth.

II. Then one Sunday morning in May. 1985

Eureka moments happen only for those who are prepared to receive it. I was looking through the Home section of the Sunday Milwaukee Journal and my eye was caught by an ad about a "unique" underground home that was be open for tours 20-some miles NW of where I lived. I got in my car and headed out to see "**TerraLux**" -Earth- Light.

Prior to this day, I had accepted that future Lunans would live like moles, in underground warrens as Robert A. Heinlein described them in his classic science fiction novel, "The Moon is a Harsh Mistress." Life underground would be protected from harsh cosmic weather, meteorite impacts and thermal extremes.

But here was a home, unlike the usual "Earth-sheltered" homes of the period, without an exposed southern exposure window wall for thermal input. It was all underground, with access through a partially exposed garage. But enter, and wow! The home was flooded with sunlight, and in every wall was a picture window showing the beautiful Kettle Moraine glacial countryside without. You can read about this in "**M is for Mole**", MMM #1, online at:

http://www.lunar-reclamation.org/mmm_1.htm

This article is also reprinted in MMM Classics #1 www.moonsociety.org/publications/mmm_classics/

Well, the long and the short of it is that I never wrote the novel, but all the research I had done to show just how we could rise to the Challenge of the Moon would find its way into articles in Moon Miners' Manifesto illustrating how pioneers would live and thrive on the Moon, and become "at home" there. Sixteen months after the "Eureka" experience at TerraLux, a team of L5 Society "colonizers" from Chicago and the Twin Cities descended upon Milwaukee to talk to at large L5 members in the area, and the rest is history. These two beginnings are still "powering" MMM, and the Lunar Reclamation Society.

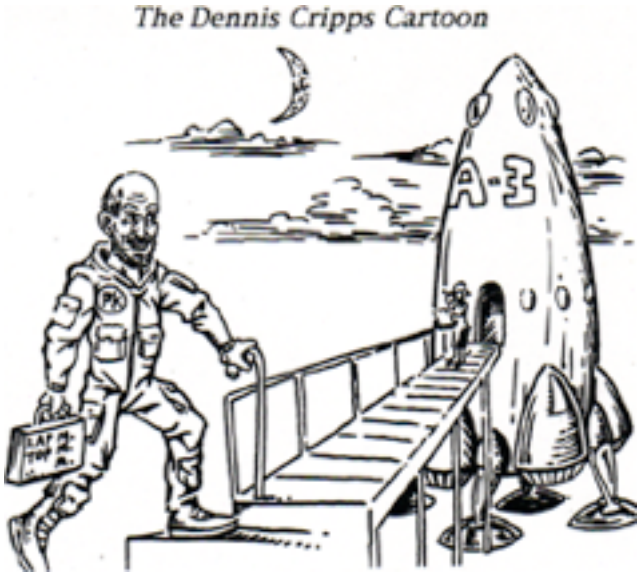
We have every intention of keeping on going. **PK**

And that is how we got to today

Here it is, December 3, 2006, LRS and MMM will be celebrating our 20th anniversary at our annual holiday party in a few days, and the only way we are going to get to the Moon in time to publish #201 from Luna City, is aboard an alien UFO!

But it feels good in the interim,to have completed archiving all the timeless articles from the first fifteen years. The MMM Classics will be extended through #150 (the first 15 years) as there are individual pdf files from there on. It continues to be a very rewarding blast!
{With this issue of the Classics, the first 21 years are preserved in this fashon] Peter Kokh

[**Out of the Past**, from MMM #101, **ten years ago!**]



The MMM Editor boarding the Moonship for Luna City
On Completing the First Ten Years of MMM

Someone in the Artemis Society asked me, ten years ago, then that with the next issue, MMM #101, when we would be celebrating our 10th anniversary of continuous publication, where I'd like to see us, and myself in another 10 years, on the eve of publishing MMM #201, the 20th anniversary issue. Without hesitation, I said that it was my dream to publish that issue on the Moon. Or rather the first issue of **"Mother Moon News."** **PK**

The Visible Exterior of "Terra Lux"

The Experience that still Inspires MMM

One sunny Sunday, in May 1985, I toured a most unusual "Earth-sheltered" home, in the Kettle Moraine Hills 20 miles northwest of Milwaukee. Its "periscopic" picture windows, and sun-following heliostats brought the views and sunshine inside in a way I had never experienced before. Heinlein may have been right about future Lunans having to live underground, *but they could take the sunshine and views down with them!* For more, visit:

http://www.lunar-reclamation.org/mmm_1.htm

Beyond Our First Moonbase:

The Future of Human Presence on the Moon

By Peter Kokh kokhmmm@aol.com

Beginnings

If all goes as planned, U.S. budget crises notwithstanding, mankind's first outpost on the Moon will start to become real around 2020, a historic event, that were it not for politics, might have happened decades earlier.

The vision outlined in **The Moon: Resources, Future Development and Settlement**, by David Schrunk, Burton Sharpe, Connie Cooper and Madhu Thangavelu is a bold one, showing how we could set up our first outpost so that it would become the nucleus from which human presence would spread across the face of the Moon.

NASA itself has such a vision, but the agency can only do what it is authorized to do. If the history of the International Space Station offers clues, NASA's official goal, which only includes setting up a first limited outpost as a training ground for manned Mars exploration and nothing more, will be under increasing budgetary pressures to slim down into something with no potential for growth at all. The intended crew size, the planned physical plant, and the capabilities that are supported, will all be tempting "fat" for budget cutters who cannot see, or appreciate, the possibilities beyond. This is the risk of publicly supported endeavors in space. It is difficult to get political leaders, and the public itself, to look beyond very near future goals. The chances that our first outpost will be born sterile cannot be dismissed.

But if private enterprise is involved and ready to take over when and where NASA's hands are tied, there could be a bright future for us on the Moon. Much of that promise may involve finding practical ways to leverage lunar resources to alleviate Earth's two most stubborn and intertwined problems: generating abundant clean power, and reversing the destructive pressures of human civilization on Earth's environmental heritage.

Cradlebreak: early lunar building materials

The Moon has enormous resources on which to build a technological civilization. But first things first. How can we break out of a first limited-vision outpost? A humble start can be made by demonstrating the easier, simpler ways to start lessening the outpost's heavy dependence on Earth. Oxygen production comes first. Close behind is hydrogen harvesting, whether from lunar polar ice deposits or from solar wind gas particles found in the loose regolith blanket everywhere on the Moon.

If we have access to basalt soils in the frozen lava floods of the *maria*, we can cast this material into many useful products. Not the least of those are pipes, sluices, and other components of regolith handling systems: cast basalt is abrasion-resistant. If we expand the outpost with inflatable modules shipped from Earth at significant savings in weight per usable volume over hard-hull modules, we can use cast basalt products, including floor tiles and tabletops to help outfit these elbowroom spaces. We can learn from a thriving cast basalt industry on Earth.

Experiments done on Earth with lunar simulant, of similar chemical and physical composition to lunar regolith, then repeated with precious Apollo moondust samples, give us confidence that concrete and glass composites will be very important in any future construction and manufacturing activity on the Moon. We could make additional pressurizable modules from fiberglass reinforced concrete or glass composites. We can make spars for space frames and many other products out of these composites as well. The Moon's abundant silicon will allow us to make inexpensive solar panels for generating power. Production of usable metal alloys will come later. The Moon is rich in the four "engineering metals:" iron (steel), aluminum, titanium, and magnesium.

An Industrial Diversification Strategy with maximum potential for cutting dependence on Earth imports .

The name of the game is Industrial "MUS/CLE." If we concentrate on producing on the Moon things that are **M**assive, yet **S**imple, or small but needed in great numbers (**U**nitary) so as to provide the major combined tonnage of our domestic needs, we will make significant progress towards lessening the total tonnage of items needed from Earth to support the expansion effort.

Until we can learn to make them ourselves, we continue to import the **C**omplex, **L**ightweight, and **E**lectronic items we also need, but which together mass to much less. It would be very helpful to the success of such a strategy, to design everything needed on the Moon as a pair of subassemblies, the MUS assembly to be manufactured locally, and the CLE assembly to be manufactured and shipped from Earth, both being mated on the Moon.

Simple examples are a TV set: works manufactured on Earth, cabinet on the Moon; a metal lathe built on Earth, its heavy table mount manufactured on the Moon; steel pipe and conduit on the Moon, all the fittings and connectors from Earth. You get the idea.

As the population of pioneers and settlers grows, and our industrial capacity becomes more sophisticated and diversified, we can assume self-manufacturing of many of those items as well. Making clear and steady progress in assuming an every greater share of self-manufacturing physical needs is essential if we are going to encourage both continued governmental support and attract every greater participation by private enterprise.

Paying for the things we must import .

Seeing that Earth seems rather self-sufficient, and products from the Moon would be expensive, many writers have concentrated on trying to identify "zero

mass products" such as energy, to provide the lunar settlements with export earnings. The need for exports is indeed vital. As long as the settlement effort must still be subsidized from Earth, there will always be the risk of unrelated budgetary pressures on Earth fueling support for those who would pull the plug on lunar operations.

Thus it is vital that settlers develop products for export to help them pay for what they must still import. Only when we reach import-export parity, will the lunar settlement have earned "permanence." Permanence can't be simply declared. Tagging NASA's first moon base as "a permanent presence on the Moon" is in itself just so much empty bravado. If we do not begin developing and using lunar resources seriously and aggressively, the effort will fail of its own costly weight.

Now here is the point where many will balk. Yes, there are grandiose plans to use lunar resources to build giant solar power satellites in geosynchronous orbit about the Earth, or to build giant solar farms on both the east and west limbs of the Moon to beam power directly to Earth, and/or to harvest precious Helium-3 from the lunar topsoil or regolith blanket, a gift of the solar wind buffeting the Moon incessantly for billions of years, the ideal fuel for nuclear fusion plants. But none of these schemes will materialize right away. Meanwhile what do we do? Cannot anything the Moon might manufacture to ship to Earth be made less expensively here at home? No!.

But that does not matter. Earth itself is not the market. Developing alongside of an upstart settlement on the Moon will be tourist facilities in Earth orbit. And that is something the lunar settlement effort can support. Anything future Lunan pioneers can make for themselves, no matter how unsophisticated in comparison with the vast variety of terrestrially produced alternatives, can be shipped to low Earth orbit at a fraction of the cost that functionally similar products made on Earth can be shipped up to orbit. It is not the distance that matters, but the depth of the gravity well that must be climbed. It will take one twentieth of the fuel cost to ship a set of table and chairs, a bed frame, interior wall components, floor tiles, even water and food, from the Moon, 240,000 miles away, than from Earth's surface, 150 miles below.

Thus, in the near term, the future of Lunar Settlement will be closely tied to the development of tourist facilities, hotels, casinos, gyms, etc. in orbit. This sort of development will start to bloom about the same time as a lunar settlement effort starts to break out of an initial limited moonbase egg. But the linkage will become visible much earlier: it is very likely, that the first space tourist will loop-the-Moon, without landing, before the first astronaut since Apollo 17 in 1972 sets foot on the Moon. The Russians say that they can provide such a tourist experience, skimming low over the Moon's mysterious farside, in just two years after someone plunks down $100 million. That will indeed happen, and it will create a benchmark that others will want to follow, inevitably brining the price down for a ride to an orbiting resort.

The Moon from a Settler's Point of View

Magnificent Desolation? Yes. Harsh and unforgiving? That too. Alien and hostile? Of course! It has always been so from the time our ancestors on the plains of East Africa started pushing ever further into unfamiliar lands: the lush, dense jungles, the hot dry deserts, waters too wide to swim, high mountain ranges, and eventually, the arctic tundra. Judged by the pool of past experience, each new frontier was hostile, unforgiving, and fraught with mortal dangers .. until we settled it anyway.

Once we learned how to use unfamiliar resources in place of those left behind, once we learned how to cope with any new dangers, as if by "second nature," then the new frontier becomes as much home as places we left behind. Anyone raised in a tropical rain forest, suddenly transported to Alaska's north slopes, might soon perish, unable to cope. The Eskimo never gives it a second thought. How to cope with ice, cold, the arctic wildlife, the absence of lush plant life, has become second nature.

And future Lunans will reach that point as well Yes there is sure suffocation outside the airlock. Yes the sun shines hot and relentlessly with no relief from clouds for two weeks on end. Yes the Sun stays "set" for two weeks at a time while surface temperatures plunge. Yes the moon dust insinuates itself everywhere. The litany goes on and on. Lunans will learn to take it all in stride. How to take due precautions for each of these potential fatal conditions will have become culturally ingrained 2nd nature. The Moon will become a promised land to Lunans.

Making ourselves at Home

Even in the first lunar outpost, crew members could bring rock inside the habitat as adornment in itself, or perhaps carve one into an artifact. An early cast basalt industry, early metal alloys industries, early lunar farming, will all supply materials out of which to create things to personalize private and common spaces alike. Learning to do arts and crafts on the Moon may seem useless and irrelevant to some, but it will be the first humble start of learning to make the Moon "home." And so it has been on every frontier humans have settled.

We will also learn to schedule our activities and recreation in tune with the Moon's own rhythms. We'll do the more energy-intensive things during dayspan, the more energy-light, manpower-intensive things saved for nightspan. With no real seasons, the monthly dayspan-nightspan rhythm will dominate. The pioneers may bring some holidays with them, but will originate other festivities and both monthly and annual celebrations.

Getting used to lunar gravity will also help the pioneers settle in. They will quickly abandon trying to adapt familiar terrestrial sports, which can only be caricatures of the games of Earth. Instead, they will invent new sports that play to the 1/6th gravity and traction, while momentum and impact remain universally standard. Alongside the development of lunar sports will be forms of dance. Can you imagine how ethereal a performance of Swan Lake would be on the Moon? How many loops could an ice-skater do before finally landing on the ice? .

But they have to live underground, for heaven's sake! .

On Earth, our atmosphere serves as a blanket which protects us from the vagaries of cosmic weather: cosmic rays, solar flares, micrometeorite storms. If our atmosphere were to "freeze out" it would cover the Earth with a blanket of nitrogen and oxygen snow about 15 feet thick, and still provide the same protections.

On the Moon, eons of micrometeorite bombardment have pulverized the surface and continue to garden it into a blanket of dust and rock bits 10-50 feet thick. Tucking our pressurized outpost under such a blanket, will provide the same protection, along with insulation from the thermal extremes of dayspan and nightspan.

Will our outposts look like somewhat orderly mazes of molehills? To some extent, perhaps; but the

important thing is that we do not have to live as moles. We have ways to bring the sunshine and the views down under the blanket with us. In the spring of 1985, I had the opportunity to tour a very unique Earth-sheltered home 20-some miles northwest of Milwaukee where I live. Unlike typical earth-sheltered homes of the period, TerraLux (EarthLight) did not have a glass wall southern exposure. Instead, large mirror faceted cowls followed the sun across the sky and poured sunlight inside via mirror-tiled yard wide tubes through an eight-foot thick soil overburden. Periscopic picture windows provided beautiful views of the Kettle Moraine countryside all around. I had never been in a house so open to the outdoors, so filled with sunlight, as this underground one. At once I thought of lunar pioneers, and how they could make themselves quite cozy amidst their forbidding, unforgiving magnificent desolation. The point: yes, the Moon is a place very alien to our everyday experience. Nonetheless, human ingenuity will find a way to make it "home."

What about us outdoorsmen?

While Lunans will find plenty do do within their pressurized homes, workplaces, and commons areas, many will miss the pleasures of outdoors life on Earth: fishing, swimming, hunting, boating, flying, hiking and mountain climbing and caving. The list goes on and on.

Yet some of these pleasures we may be able to recreate indoors, fishing in trout streams, for example. We will want an abundant supply of water, and waste water in the process of being purified can provide small waterfalls and fountains, even trout streams for fishing and boating. In large high ceiling enclosures, humans may finally be able to fly with artificial wings, as Icarus tried to do.

Out-vac, out on the vacuum washed surface, it will be more of a challenge. Present space suits are too cumbersome, too clumsy. We need suits that offer more freedom of motion, that tire us less easily. Then out-vac hiking, motor-biking, mountain climbing, and caving in lavatubes will become practical. Out-vac sporting events, rallies, races, and games will follow. As we learn to take the Moon's conditions for granted, and to "play to them," we'll invent sporting activities that suit the environment.

Agriculture and minibiospheres

The idea of going to the Moon with sterile tin cans and a life-support system tucked in a closet with a few token house plants thrown in for good luck is absurd. As it happens, NASA has abandoned "Advanced Life Support." Instead we have to approach creation of living space on the Moon as a mating of modular architecture with "modular biospherics." Every pressurized module should have a biosphere component, so the two, living space, and life in that space, grow a pace, hand in hand. The clues are not in the organic chemistry labs but in the many down to earth "back to earth" experiments thriving on Earth as we speak. Earth life must host us on the Moon even as it does on Earth, not vice versa. Lunar settlements will be "green" to the core. And we will feel at home.

One settlement, a world "doth not make"

The Moon's resources are not homogeneously situated. A site handy to polar ice reserves will not be near mare basalts, nor iron and titanium rich ilmenite, nor vast underground caves formed long ago by running lava. As the lunar economy expands, we will need to establish settlements in a number of differently advantaged areas. And that will make the Moon a real "world." Lunans will be able to travel elsewhere, get away from it all, experience cultural, artistic, archeological, and climate variations. Even as an outpost cannot be "declared" permanent, neither can a solitary settlement. No matter where we choose to set up shop first, we need a global vision. The authors have this vision, and their brilliant concept of a lunar railroad network illustrates that well.

Getting through the Nightspan

To many people spoiled by abundant energy "on demand," the need to store up enough energy during the two week long dayspan to allow the outpost to not just survive the nightspan, but to remain productive is daunting. Yet all of human progress is built on utilizing various forms of power storage, starting with firewood. Even in nature, the spread and survival of species has turned on this point, from bear fat to squirreling away nuts. The problem is one of attitude. Those with the right attitude will find a way, many ways in fact. The same goes for managing the thermal differences between lunar high noon and predawn. Since we first began to move out of our African home world to settle the planets of Eurasia and the Americas, we have tackled harder problems. Those not intimidated by the challenge will lead the way.

The pattern emerges

Lunan pioneers will make progress in all these areas together: providing the bulk of their material needs by mastering lunar resources; becoming ever more at home through lunar-appropriate arts, crafts, sports, and hobbies; creating a uniquely Lunan culture. this process must start immediately. The first outpost should be designed to encourage, not discourage experimentation by those with the urge to create and fabricate with local materials. Things shipped from Earth should be designed and manufactured in MUS/CLE fashion, so that their simpler and more massive components, made on Earth can be replaced with parts made on the Moon, freeing up the original parts for reuse. Parts made here of elements hard to produce on the Moon, like copper or thermoplastics, will help spur infant lunar industry at a quicker pace.

The Necessary Gamble

It is predictable that NASA, however free the life styles of its individual employes, will continue to take a conservative stance on fraternization between outpost personnel. It is predictable that there will be an absolute ban on pregnancies. Yet, this is something that cannot be conveniently postponed. The only way to know for sure if infants born on the Moon will turn out to be healthy, is to see how the second native born generation turns out. Will they be fertile? Experiments with animals with much shorter life cycles will give us debatable clues. There is but one way to find out for sure. Do it! Take the plunge.

Official policy may be quite strict and allow no exceptions. But then individuals will take matters into their own hands. Confidence in this outcome will grow, if there are for-profit commercial outposts on the Moon.

As long as we play the "outpost game," and that is what it is, of rotating crews with short tours of duty, as long as we avoid allowing people to choose to live out their lives on the Moon, raising families, as nature dictates, we will not see the rise of a lunar civilization, nor real use of lunar resources to help solve Earth's stubborn energy and environmental needs in sustainable fashion. Human choices must be taken out of the hands of politicians and administrators afraid of conservative

opinion. Nations may build outposts, but only people pursuing personal and economic goals can give us settlement. If history is any guide, that is exactly what will happen.

Antarctic outposts are a dead-end paradigms no real use of local resources, no economic activity, no real society. For the Moon, we see instead, a real human frontier in which an initial small outpost will seed a self-supporting frontier of hundreds of thousands of pioneers in a number of settlements. Many of these Lunans will be native born, others fresh recruits from Earth seeking the promise of starting over, starting fresh, getting in on the bottom floor. Throughout history, those doing well stayed put. Frontiers have always been pioneered by the talented but "second best" seeking a more open future.

The Moon will become a human world. **<MMM>**

An Unfulfilled MMM Dream

The LUNAR HOMESTEAD Show

By Peter Kokh

This idea came out of the initial brainstorming of a comprehensive program for a Milwaukee-hosted International Space Development Conference. David A. Dunlop and I had started putting together ideas for our ISDC bid for the 1997 slot on our way home from the 1993 ISDC Huntsville, Alabama. (Our bid lost by a one vote to Orlando. We rebid and won the 1998 slot but notwithout a penalty of bashed enthusiasm on our team. We would never go through a rebid process again.)

The **Lunar Homestead Show** was to be a grand exhibit of technology that could make a pioneer home comfortable and inviting. It would be a concrete illustration of many of the ideas we have talked about in the pages of Moon Miners' Manifesto through the years.

We had a long list of exhibit items, but only four were actually produced.

- The prototype of the now famous "gravity bricks"
- A table top modular pioneer homestead on an 80" by 36" hollow core door (pictured on page 1 bottom RT)
- a demonstration model of a ""Z-view" periscopic picture window.
- exhibits of lunar paintings done with metal oxides in sodium silicate on the reverse side of a glass pane.

The other items on our list were casualties of money, available labor, and time, but mostly the latter. Among the ones not realized were practical items such as how pioneers could build interior walls, and decorative items made of cast basalt, raw glass made from fused regolith, sintered iron fines, etc.

It was our hope to add to our initial offerings as time went on. The exhibit had been conceived as a traveling show that we hoped could be included in every other ISDC. But this did not materialize either, and for one simple reason: no place to store any additional items!

But then, if we solved that problem somehow, we'd still have the problem of mobility: getting items out of storage and to exhibit places.

The dream is still alive

But the dream is still alive. If we find the funds to begin erecting an analog moonbase research station, with a modular architecture, build-as-you-go fashion, and if we built alongside of it a growing integrated tourist facility, lunar "homestead items" could provide some of the furnishings and much of the atmosphere.

The proposed tourist facility would have a one-way mirror connection to the research facility. Visitors could observe what is going on in common areas of the facility, but would be invisible to the research crews, and thus not a distraction. Infrequent invasions of Mars Desert Station surroundings by the curious are often very disruptive.

Now the dream of the Lunar Homestead Show is hitched to the dream of an ever-growing modular (architecture and biosphere) Lunar Outpost Analog, tasked with demonstrating the technologies needed to "break out" of an initial small science outpost, towards resource-using, import-defraying, export-producing lunar settlements. Everything fits together! **<MMM**

MODULAR BIOSPHERICS

Making the most of pressurized pedestrian & vehicular corridors:

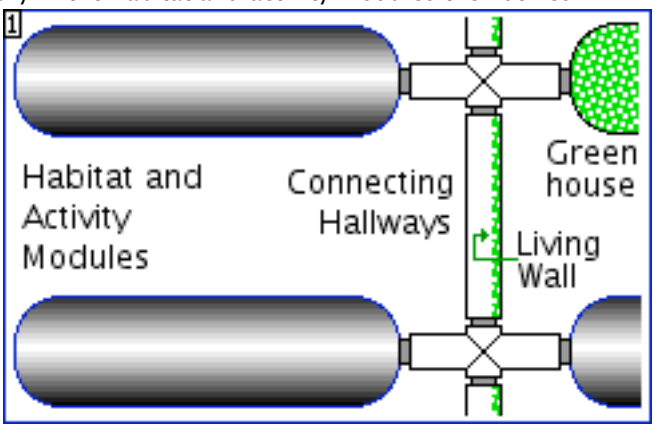
"*Living* Wall Systems"

By Peter Kokh

> "A **living wall** is a vertical garden. Plants are rooted in compartments between two sheets of fibrous material anchored to a wall. Water trickles down between the sheets and feeds moss, vines and other plants. Bacteria on the roots of the plants metabolize air impurities such as volatile organic compounds."
> http://en.wikipedia.org/wiki/Living_wall

While this is the definition in the most technical sense, experimenters have made living walls in which plants are in pots anchored to a wall in a staggered pattern. They have also found other ways to keep them properly watered, fertilized, and to recycle the drainage water. Illustration 2 below is an example of the first approach, illustration 3 below the latter.

In a modular outpost, there will be connecting tubular passageways for pedestrians and small carts. Their curved walls offer an opportunity to increase the overall biosphere mass of a lunar outpost (real or analog) by integrating a living wall feature along one side, for the whole length of (each) hallway. This will be in addition to the biomass contributed in any Greenhouse modules and any in the habitat and activity modules themselves.

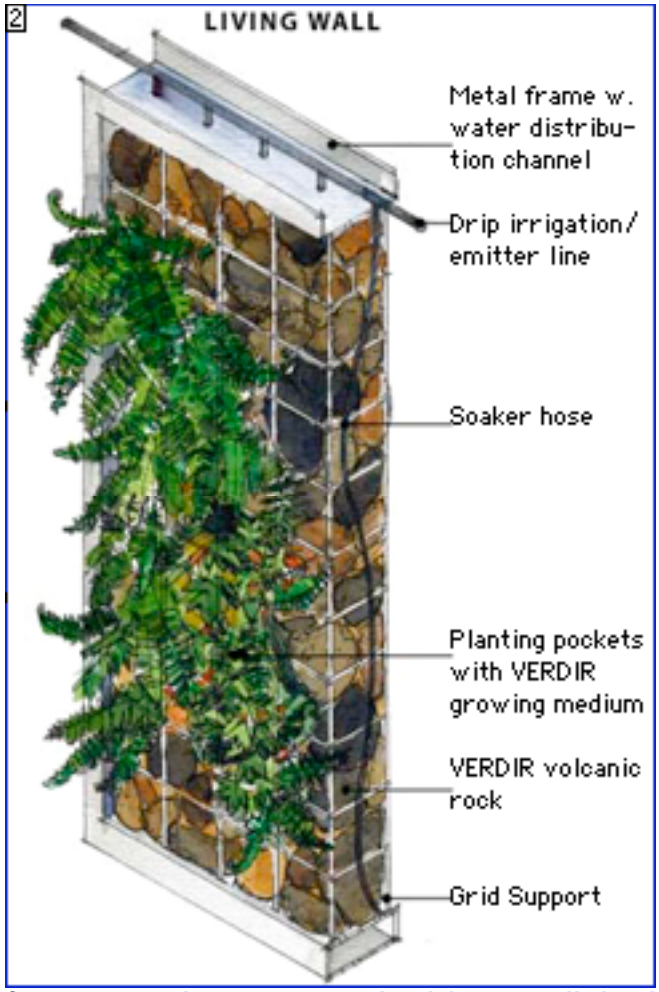


In a larger settlement, pressurized roads could have living walls to each side, and, down the middle, to sepa-rate traffic flowing in opposite directions, boulevard style.

If we continue to think in terms of floor space, then we will be put in competition with the plants we depend on - not a prescription for success. But plant areas can make use of otherwise empty wall space.

"Waste no opportunity to include more plant life, want not for your next breath" to paraphrase an old saying.

If we are talking about an open-ended installation (again, either on the Moon or at an analog research site) by adopting a policy that no wall should be idle, we guarantee that the modular outpost grows, a modular biosphere grows with it, neither outstripping the other. Now can there possibly be a better arrangement? Yet so far all biosphere experiments seem to be of set size, not designed to grow in modular fashion. The non-modular set-size approach tends to be an effective predictor that the installation will have no future.



from **www.verdirsystems.com/html/living-walls.html**
The above shows a technical approach.

Dr. B. C. Wolverton, doing the research for NASA, identified a dozen common house plants easily available that cleansed the air, including: gerberra daisy, bamboo palm, spider plant, marginata, mass cane, spathiphyllum, Janet Craig, and English Ivy - published in the pamphlet "Plants for Life: Living Plants Vital In Filtering Contaminated Air"- a NASA pamphlet published more than fifteen years ago.

Now Dr. Wolverton has published a much more comprehensive treatment in the book, "**How to Grow Fresh Air: 50 Houseplants that Purify Your Home or Office**" - Penguin Books ISBN 0.14.02.6242.1.

Many Living Wall installations use a system of staggered planters and integrated water features to accomplish the same ends in a more natural and beautiful fashion.

Plants to choose from
There is a wide variety of plants that provide lush green foliage while cleansing the air of toxins (to prevent "sick-building syndrome") and increase the amount of oxygen, maintaining a fresh, clean atmosphere inside.

Living Wall installation, Baltimore, MD. This 110 sq ft (10 sq m) wall filters all the air for its 7,500 sf office building. Notice the ornamental character of some plants chosen

Living Walls as Graywater Purifiers
www.holon.se/folke/projects/openliw/openlev_en.shtml

"By growing plants in a porpos wall [a special adaptation of the Living Wall concept, read on], you get both an efficient space use by vertical plant growing and purification of the percolating water, which can be grey-water." (Graywater is water from sinks, tubs, and showers, and previously treated blackwater from toilets.)

"The hollow parts of the stones are filled with inert material, like gravel, LECA-pebbles, perlite or vermiculite. The stones are placed so the water will percolate in zigzag through the wall. Bacterials in the porous material break down organic pollutants. The

water trickling down through the wall will nourish the plants at the same time as it will be purified The plant roots will grow into the inert material and extract nutrients from the water. Over the pebbles, a bacterial film of will grow. After comsuming organic material they release the nutrients in the percolating water. The plants will take up the nutrients and subsidize the bacteria with sugar from their photosynthesis.

"By this, you get both vertical growing & grey-water purification. Therefore, the efficiency of the purification is dependent on the amount of solar radiation reaching the plants in the wall."

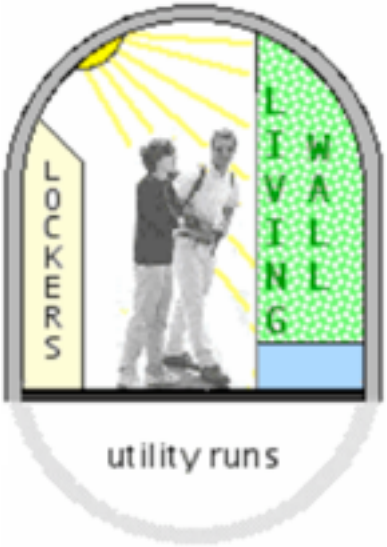
[web source cited above.]

Air Circulation Systems

"Active walls'" are also integrated into a building's air circulation system. Fans blow air through the wall and then recirculate the refreshed air throughout a building. These indoor living walls help prevent and/or cure what is known as "sick building syndrome" by increasing air oxygen levels.

Integrating Water Features and Fish

Some Living Walls integrate fish ponds at the foot of the wall as part of the system where trickling water collects before it is pumped back up to the top of the wall.' The foliage purifies the graywater, digesting the dissolved nutrients. Thus a living wall can be an integral part of water purification and reuse, not just fresh air.



Left: Cross-section of a hallway corridor in a modular Lunar Analog Research Station - or in an actual Moon Outpost **Decorative Options:** It is easy to work in rocks and planters, sculptures and other objects into a living wall system. These can be design accessories or fully functional parts of the plant holding and water irrigation systems.

A living Wall is something to be designed to suit taste as well as to serve function. In a modular (analog or real) lunar outpost, each hallway could boast its own design, creating a more interesting working an living environment as well as a fresher, cleaner, healthier one.

You can go high-tech, but this is not necessary, and the cost-benefit ratios of a high-tech approach are probably not great. Low tech is always better *if it works.*

Using all Opportunities to increase biomass

We tend to make the mistake of describing living space volume in terms of square footage of floor space only, neglecting the opportunity walls provide. Counting all surfaces is the secret of packing a bigger biosphere into a smaller space: using walls, and even ceilings!

It is important, if we are going to bring the biosphere truly inside, to build our environment with mold-resistant surfaces. This means giving careful consideration to materials and surface coatings, as well as due humidity control and ventilation.

Sunshine, or its equivalent

Proper light must be brought in by light pipes, clerestories, or grow-lamps: a separate, related topic.

Purposes of a System of Living Walls in an Outpost

- Purify and freshen air; purify graywater
- Provide lush greenery, color, interest
- Provide herbs, spices, berries, etc.

and last, but not least, to

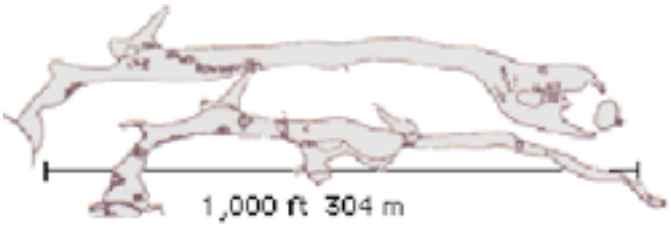
- **Psychologically "reencradle" crews in a mini-biosphere <MMM>**

Usefulness of Terrestrial Lavatubes in a Lunar Analog Research Station Program

By Peter Kokh

In August 1992, I had the wonderful experience of a personal guided tour of the pair of lava tube caves outside Bend, Oregon that the Oregon L5 Society was using for outpost simulation purposes. My guides were Bryce Walden and Cheryl Lynn York of Oregon L5.

Oregon Moonbase Photo taken during a simulation. The PVC tube frame would be covered with a tarp to serve as a makeshift base for students. The cave floor is flat due to the invasion of volcanic ash from the explosive eruption of Mt. Mazama 4,800 BC that formed the jewel known as Crater Lake, 85 miles to the WSW of Bend.



Above: Young's Cave complex outside Bend, OR.

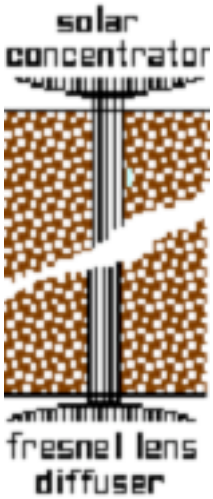
Lavatubes on Earth are much smaller in scale than those on the Moon, probably in some inverse relationship to gravity. The widest portion of the Young's Cave complex is 79 ft., the greatest ceiling clearance 26 ft. but these dimensions are uncommon. Because of their much smaller scale, they are hardly simulation stand-ins for those on the Moon. But we can put them to some use. And on July 20, 1989, NASA granted the Oregon chapter $25,000 to do a thorough site characterization.

The Geological survey was done by Stephen L. Gillett, a consulting geologist now in Carson City, Nevada with U-NV-Reno. Century West Engineering of Bend did

the engineering analysis. A series of 5 borings, in roomy locations specified by Oregon L5, showed the roof to be generally from 10 to 20 feet thick with 7-19 ft of hard basalt overlain by 0-3 ft of loose soil. Except for a few transverse cooling cracks, the ceiling is relatively intact and rock quality analysis shows the roof could support from 2-60 tons suspended weight per linear foot, depending on varying roof thickness and the presence presence or absence of fractures. For this, a system of rock bolts will do. In weak areas, roof-shoring supports are advised. Some 6000-7500 cubic yards of sand forms a floor 0-6 ft thick. This could be removed, if desired, by vacuuming. Rock debris could also be removed, if desired, by backhoe or by hoists through openings made in the roof, thereafter available for installation of equipment. But creating such openings whether by blasting, jackhammer, or rocksaw would be a major undertaking. The variations in surface terrain were also surveyed.

The estimated cost of preparing the site as a major lunar analog facility as outlined by the Oregon Moonbase team was over $6 million 1990 dollars. The Phase II grant never came. Eventually, the chapter decided to let the renewable 5-year lease on the facility expire.

But on the basis of what we learned about this pair of lavatubes during the study, we think that this facility, if we could regain access, or a similar tube elsewhere, could support unique simulation exercises. If the main moonbase facility was up on the surface nearby and only limited simulations done in the lavatube, the cost could be significantly lower, with a very modest initial presence expanded on a pay-as-you-go basis.



The five 60 mm (2 3/8") bore holes through the tube roof-ceiling could be used to drop in miniaturized survey equipment designed to demonstrate how we can robotically map the interior of lunar lava tubes, profiling their complex shapes and cross-sections. These tests finished, the bore holes could be filled with fiber optic bundles to let in sunlight concentrated up to thirty times. One bore hole could be used for communications access.

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A small Habitat complex could be put together out of small inflatable units or of EZ assemble-disassemble semi-prefab structures. At such a facility, where, within the lavatube, lighting would be totally controllable, we could more easily simulate the lunar dayspan/nightspan cycle. We could examine ways of dealing with the two week long nightspan that would let a crew remain productive throughout. We would try to determine hwlittle power we could get by on and still be productive, concentrating on repairs, maintenance, inventory, and other power-light, manpower-intensive tasks, so as to better use the 15 days of dayspan solar power available to store up power to tap after lunar sundown.

Meanwhile, a nearby surface conventional outpost complex would investigate and demonstrate other things: teleoperations; in situ resource utilization; shielding options; and many more lines of investigation. While it would be ideal for the companion analog surface outpost to be very close to the lavatube entrance, a separation of a few miles should not hinder operations. Crew would go from one to the other in a "pressurized vehicle." This allows room for latitude if it is not possible to have both outpost components closely collocated.

If the access to the Bend, Oregon site can't be recovered, we might do something similar at lavatube locations at Craters of the Moon National Park, ID; El Mapais National Monument, NM; or Snow Canyon State Park, UT. The advantage of Bend is that the lavatube complex there is well known and studied, and familiar to a number of Moon Society members. **MMM**

An Ode to MMM on its 20th Anniversary

By David A. Dunlop - December 9, 2006

The Moon in night's sky
Delights a wide eye,
Hanging in Space, yet showing
A cratered pocked face.
Her light is for lovers and makers of dreams, but
this blue-yellow orb is more than it seems.

From Apollo's few footprints and that harried race
We learned quite a lot from that rocky place.
Bathed in winds of Sun's fusion breath
Is a dry barren world and of water bereft.

Perhaps at the poles in an icy rock stew
We may manage to gulp an ice beverage or two.
From Aitken's deep basin To Malapert's height
We hope to find power in continuous light
Which mingles with dust at the Moon's terminator
and charges that dust as a great levitator.

Sun's Coronal ejections are fusion flung ways
Of cosmonaut cooking, plus
Hard gamma rays!

These brave lunar settler's at first will be few
But hope to find shelter in Moon's lava tubes.
The sinuous chambers in Mare's hard rock
are Bryce Walden's passion and knowledge- trade stock.

With KREEP enriched soils, and Titanium basalt,
Anorthosite highlands and deep lunar faults
We'll study and master the hard lunar ways
Of living on Moon land for 14 day days
And 14 day nights, as the lunar day goes.
This lunar progression makes horizon glows
and transient effects from hidden gas flows.

It's hard scrabble living from in situ stocks
Of lunar sourced treasures and lunar source rocks

But Moon Miner living is coming to stay,
From 20 years' thinking from the Great Peter K!

Thanks, Dave, but I do it because I love doing it. - PK

The Modular Biosphere

It makes no sense at all to look for centralized solutions to the need to grow and sustain a minibiosphere that can in turn sustain lunar and/or Martian pioneers. All human communities either grow or petrify. We must design each structural module, be it residential, office, commercial, school, industrial or agricultural space to contribute its share to the total biomass. In this issue, we look at the "Middoors" contribution.

There are three principal human space expansion pathways advocated by persons preoccupied with three principal imperatives. Each of them sees space as key to the ultimate challenge facing humanity: survival.

1. **Planetary Defense of our homeworld from potential impactors (Near Earth Asteroids)**
2. **Establishment of a viable exclave of human civilization on another world (Mars)** to guarantee human survival should civilization on Earth fall victim to an impacting object, or implode through overpopulation and human-caused environmental degradation
3. **Using space resources to halt and ultimately reverse environmental degradation on Earth** through overuse of fossil fuels, and to make possible a more equitable global economy **(The Moon)**

First, let's go into a bit more detail on each of these rationales for human expansion into space. Then, I want to suggest why the Moon Society should, rather than concentrate solely on the third, be deeply concerned and involved in all three.

What follows is a first draft of a talk planned for MarsCon 2007 in Minneapolis-St. Paul on March 3rd. My intention is to develop it into a position paper to propose for adoption by the Moon Society Board of Directors as a guide to the Society's future.

Let's look at the three more closely.

1) Planetary Defense:

We need to mitigate the very real threat that a large population of near Earth objects, many as yet to be detected or tracked, could in some time from today into the far future, cause significant destruction on Earth by impacts that could conceivably wipe out whole cites, devastate a continent, even cause mass extinctions on a global scale. There is no way of knowing whether one of these potential varmints might strike Earth in our lifetimes, or within the next millennium, or within the next 100,000 years. The point is, the danger is finite, and since it is conceivable that we could intervene successfully to ward off individual threats, we ought to prepare ourselves to do so. That said, it is necessary to pick or battles, choosing the most bang for the least bucks. That starts with detection, orbit tracking, and cataloging object masses and compositions. But to put the risk in perspective, weighting proximate danger more heavily, the risk of making much of Earth uninhabitable within this century by our own thoughtless habits is more real, more urgent.

Back to NEOs: Compositions are important when it comes to choosing methods of orbit correction and threat removal. Some of these objects may be solid; how they would behave in various schemes to alter their orbits will be easier to predict. Others are deeply fractured or fragmented, or even just loose aggregations of previous impact debris - literally, giant beanbags in space. Altering their orbits will be quite a challenge. Others may be dead comets, with icy snowball cores covered with dust and hydrocarbon fallback gunk deep enough to choke any further cometary outgassing.

How can the Moon fit into Planetary Defense initiatives? I propose first of all, that we attempt to identify any advantages to placing automated, teleoperated telescopes on the Moon dedicated exclusively to the detection, tracking, and classification of the near Earth object populations. In the process, we are sure to identify asteroids with resources needed for the expansion of the lunar economy, and in orbits that are relatively easy to reach. It will be in the interests of the young lunar frontier to support development of those NEO resources.

When and if a suite of possible NEO orbit modification schemes are developed, some of them may involve forward facilities on the Moon. Some of these plans may involve manned missions more economically staged from the Moon rather than from Earth.

If in modifying NEO orbits, it is feasible to shepherd some of them into stable Earth-Sun or even Earth-

Moon Lagrange areas, those rich in elements in which the Moon is deficient would become less expensive sources for such elements than upshipments from Earth itself.

Thus strategic participation in a comprehensive Planetary Defense plan could have major positive implications for the viability and industrial diversification and strength of the Lunar economy. Further, it will be a long, long time, before a lunar frontier economy could survive if contact with Earth were totally interrupted. Earth is the principal market for the Lunar economy. Protecting Earth is very much in the interests of any future Lunar Settlement Frontier Concerned organizations are:

The Planetary Society
www.planetary.org/programs/projects/asteroid_alert/
www.planetary.org/programs/projects/apophis_competition/

The Space-Frontier Foundation www.space-frontier.org/Projects/Moon/PressReleases/20020712planetarydefense.html
http://www.planetarydefense.info/
http://en.wikipedia.org/wiki/Planetary_defense

I propose that we open the door to collaboration with these organizations in the development of a thorough Planetary Defense knowledge base and systems.

2) Long term Survival of the human race:

Establishment of a self-sufficient exclave of human civilization on Mars in the event that human civilization on Earth implodes from the combined pressures of overpopulation and environmental degradation, and possible killer impacts is a priority goal shared by many. Their number should include us, not just Mars advocates.

Mars does have more indigenous resources than the Moon to support a substantial frontier population. "More" is an understatement. Yet Mars' present climate is not very attractive and it beats me how people who have made life style decisions to move to warm sunny climates can say with internal honesty that they would be willing to help pioneer a world where the temperature range is more akin to that of Antarctica. They talk the talk but can they walk the walk?

But that is neither here nor there. Mars is the best place in our Solar System to host an autonomous human civilization that can survive whatever may happen to Earth either by way of natural disaster or via prolonged human stupidity, very much in evidence.

Why is it in the interest of the Moon Society to support the opening of a human frontier on Mars? One word: **Trade.**

The Moon lacks some of the resources needed for total self-sufficiency. This does not mean that the Moon cannot support a viable economy. Look at Japan! Japan lacked the two major wellsprings of the Industrial Revolution: coal and iron. But it had something more precious: a population that was ingenious, resourceful, and determined. This island nation developed economies beyond its shores all along the western Pacific Rim in areas where resources it lacked were abundant. These areas became its core trading partners, and Japan rose to become the second greatest economy on Earth. That it used tactics we would not tolerate today is not the point.

The Moon, hopefully with an equally ingenious, resourceful, and enterprising population, has three other major assets that more than balance those it lacks: "*location, location, location*." The Moon in fact is poised to become the Japan of Space. To realize that destiny, the lunar frontier must tap resources in shallower gravity wells than Earth's: Near Earth Objects plus Mars, and Mars' two moonlets, Phobos and Deimos. It is thus in the lunar frontier's most vital interest to support the opening of the Martian frontier. And, even though "Mars only" fans may be too defensive to see it, it is very much in the Martian frontier's vital interest to see parallel development on the Moon. Earth has little need for whatever Mars can produce. The Moon will emerge as Mars' main trading partner. The Moon in turn can trade with Earth and Earth orbiting markets.

The Moon Society can support this long range goal by prioritizing development of technologies useful on both worlds: modular architectures including

- Modular biospheric systems;
- Life support technologies
- Space suit development
- Mining, processing, and construction technologies
- Small pocket hospitals
- Agricultural and food production systems.

This is just the start of a potentially very long list. Of course some technologies that are needed on the Moon will not apply to Mars and vice versa. But considering what is to be gained by working together, that world-unique sector is trivial.

What if the Mars enthusiast community does not reply in kind? We must still support this goal. What's in it for us trumps all essentially petty considerations. If the Mars community does not respond in kind, we still stand to gain.

Nor should we fear budgetary competition! At this stage of the game, only a consortium of governments can open Mars. Meanwhile, government outposts on the Moon serve to discourage rather than encourage commercial development there, no matter what NASA may say to the contrary. NASA culture and private enterprise culture are like oil and water, SBIRs and other gestures notwithstanding. The upshot is that the Lunar Frontier and the Martian Frontier are not competing for the same financial resources I admit that there is a pro-Moon constituency still has faith in a government pioneered route and they will be fearful of getting less than their fair share of a limited budget pie. If necessary, we have to be prepared to leave those supporters behind.

The bottom line is that to be viable long term, the Moon needs Mars as a trading partner. We should, I would suggest, proclaim our support of the opening of the Mars Frontier as a goal of the Moon Society, along the lines suggested above. That does not mean that we should be preoccupied with it. It must be a secondary focus as should be planetary defense.

3) Keeping our irreplaceable homeworld blue, green, and white

To halt and eventually reverse environmental degradation or our homeworld, and underwrite economic well-being on a global basis, etc., through the use of l**unar resources to provide ample clean energy on Earth on a sustainable basis** is the third great driver for human expansion into space.

There are those who say we should tap asteroidal resources for this exclusively, on the grounds that the delta V needed to reach some of these objects is less than that needed to land on the Moon. That's find for cargo. For human missions that dynamic reverses big time. Humans need life support: air, water, food. And missions to asteroids will involve much greater travel time than missions to the Moon, where in due time, there will be established biospheres from which these consumables can be replenished. The Moon trumps with the triple advantage of "location, location, location."

For building solar power satellites, asteroid materials can be accessed more cheaply but only on an irregular "target of opportunity" basis as launch windows to objects with low delta V access are the farther apart in time the lower the delta V. This is **the catch-22 of orbital mechanics.** The closer the orbital period of two bodies (Earth and a NEO) are, the less frequent the launch windows between them.

The Moon offers the option of direct hosting of lunar solar power arrays, adjacent to, or on the very regolith covered terrain from which the building materials to construct these arrays are to be found.

The Moon also boasts immense easily recovered reserves of Helium-3, the ideal radiation-free fuel for fusion reactors, should we ever succeed in engineering them. Note that the Bush Administration killed all further research in this direction. Hopefully that will change soon.

While asteroid resources can provide some haphazard irregular sourcing of materials for solar power satellites, the Moon can supply these on a continuous conveyor belt schedule, as well as alone support the other two clean energy options identified.

Lunar development is humanity's last great hope to save Earth as the beautiful livable world we have always known it to be. It will do little good to prevent asteroid impact if we have let the Earth go to hell in a man-made basket in the meanwhile.

The upshot is that there is a logical human expansion "triway to space," and that all three portions of this triway must be pursued.

1. We must defend the planet against catastrophic impacts.
2. In the meantime, we must guarantee the survival of our species no matter what by creating a viable self-sufficient colony on Mars.
3. And we must work to halt and then reverse human-caused degradation of our homeworld environment, as can best be done by taping lunar resources for bountiful clean energy.

If the Moon Society adopts this comprehensive strategy, more space enthusiasts will find us relevant, and a dynamic society deserving their support. This strategy will also be one with which we can attempt a rapprochement with the environmental community. For if they are honest, they must support it also.

Moon Miners' Manifesto has long put out one Mars Theme special issue a year, at first on no special schedule, but for some time now, always the March issue. We have has asteroid issues, but they have been fewer, and farther in between. We'll try to correct this.

As for the Moon Society, this strategy should guide us in forging new affiliations and working agreements with other organizations and efforts. But our prime focus, both of the newsletter and of the society, will remain on the Lunar Frontier, and its mission to help reverse the environmental collapse of our beautiful and irreplaceable home planet.

Space - what's in it for the average Joe? Everything! Survival of our planet, restoration of our biosphere, a contingency exclave should disaster strike Earth despite our best efforts.

To Earth ! Finding Collaborators

One of the most frequently heard criticisms of space enthusiasts is that "they cannot agree on goals." I believe that the Triway to Space is a Roadmap that can earn majority support. But it won't come easy.

The Space Frontier Foundation and the National Space Society will be the most open to this suggestion. While the Mars Society might seem a logical partner, there is one thing about the way government space programs are currently structured that makes the Moon appear a rival rather than a partner. The best use of hard to come by financial support is to apply government financing to the NEO project and to the exploration of Mars and the opening of the Mars Frontier. And ... to the further robotic exploration of the Moon. But government plans to field a permanent lunar outpost are the fly in the ointment. Budget cutbacks rooted in the enormous financial commitment to the war in Iraq make it almost certain that if a NASA outpost is fielded, it will be stillborn in terms of capacity to do anything useful, much less grow.

As long as a sizable fraction of lunar advocates are cheering on the NASA program for the Moon, the Mars people will see the Moon as a rival, not a collaborator. Mars Society spokesmen will continue to rip apart the NASA lunar program, and to deprecate the usefulness of the Moon to solving otherwise intractable environmental and energy plans on Earth.

Should the next administration be forced by inherited budget pressures to cancel the Lunar initiative, the Mars Society may find it easier to partner with the Moon Society, if the Society officially endorses the commercial route to Lunar Settlement, which, given its roots in the Artemis Project™ would certainly seem logical. It would then be much easier to bring the Mars Society into the Triway alliance.

I am not saying, mind you, that I agree with the Mars Society's position. I don't. While the goal of setting up a second human homeworld has very high value,

working to save the one we have should take precedence. What seems imperative is to find ways to do both. Separation of funding sources would seem to be the logical first step in this direction.

We should support the Planetary Society's modest efforts at detection of threatening NEOs and its project to design "tagging" systems to place transponders on especially dangerous asteroids so that we can follow them more easily. TPS, however, has no real use for manned space efforts, with the exception of manned exploration of Mars focused on the search for life. Now it is not at all clear that the Planetary Society membership feels that way. But the hard reality is that TPS has been run as a theocracy from the outset. Members who disagree have no option other than choosing not to renew. But insofar as TPS projects are all eminently a good use of small funds, they deserve support. The upshot is that TPS will go its own way on this score, for the time being.

"Tit for tat" is a bankrupt policy, however. I recommend we support TPS (I am a long time member) even thought they may remain aloof to our concerns.

Yet even a limited Moon Society-NSS-SFF "Triway Alliance" would command growing respect from the media, a respect that has a much better chance to turn recommendations into reality, winning us all many new members who sense we have our act together. **<MMM>**

MODULAR BIOSPHERICS

II. Middoor Public Spaces as ideal Opportunities for added vegetation and even "urban" wildlife

"Middoors" MMM speak for pressurized common spaces such as pedestrian passages, streets, parks, and plazas where temperatures could be allowed to fluctuate between cool predawn lows and warm pre-sunset highs; as opposed to "indoor spaces" in private residences and in commercial, educational, office and Other fully climate-controlled areas of activity.

In the December 2006 issue of MMM # 201, we described Living Wall systems which take advantage of frequently unused or underutilized wall-hugging spaces for growing plants that will help cleanse indoor air of carbon dioxide and other airborne pollutants, boost fresh oxygen levels, and in the process create water features that could harbor fish. In this installment of our "Modular Biospherics" series, we take up the opportunities for additional vegetation in other common spaces within the outpost or settlement.

Public Squares, Plazas, Marketplaces, etc.

These will be enlarged nodes or pressurized intersections where three or more pedestrian passages and/or pressurized roads restricted to bicycles and electric vehicles come together. At least some of these intersection nodes should be enlarged to provide extra ground space for plants of various kinds, walkways, park benches, water features, etc. They should offer two more perks: higher vaulted ceilings, and overillumination.

Higher ceilings will offer welcome eye relief. The human eye has evolved to take in the sky, not just a horizon-hugging layer of vertical space. Living inside the confined vertically challenged spaces of an extensive modular maze will leave much to be desired. Yet, on the Moon at least, this may be necessary. The nitrogen needed as a neutral oxygen buffering component of breathable air will be in short supply. There are two ways to conserve the amount of nitrogen needed, and we will need to make use of both of them!

- Use one half normal air pressure, with all the hit being taken by nitrogen. That means, instead of a 79:21 nitrogen-oxygen mix, we may be using a 58:42 mix, with the actual partial pressure of oxygen unchanged. An important beneficial effect of using an 0.5 ATM pressure is that this will greatly reduce the propensity to spring leaks.
- Keep ceiling heights, and thus total volume of air needed, on the low side. I wouldn't suggest lower than 9 feet. That may seem generous, but we would be allowing for the progeny of the first settler generation to grow taller than their parents, given the low gravity.

But here and there it will be advisable, for the sake of morale, to have more spacious places in which to congregate and relax. Outdoor full sunlight level lighting and notably higher ceilings, painted a matte sky blue and brightly uplit, will subconsciously lift spirits and supply a well-needed boost. People will enjoy being there!

We have ample experience creating little urban oases for people to relax and congregate. A hard-won lesson is that as great as has been the clamor for quiet spaces apart from the hustle and bustle of life, the experience has been that such places remain almost empty, favored only by a few. In contrast, urban oases in the midst of the hustle and bustle are always the more popular. Put simply, more people enjoy relaxing where they can see and be seen. We are, afterall, social animals.

Big or small, such openings in the otherwise space-stingy modular maze of settlement outposts, they can be much greener if the vertical surfaces around the perimeter nad vertical half-wall dividers within it, are given to wall-hugging narrow trees or shrubs, or better to living walls as described in our last issue. As dividers, living wall systems can easily be configured in 2-sided fashion. Using the "hanging gardens of Babylon" approach, more floor/ground space is available to paving tiles, seating, water features, and sculptures.

If the space, say a plaza in a prospering, growing settlement, is large enough, it may contain building structures playing supporting roles: changing space for performing artists, storage space for merchant kiosks, etc. These structures may also provide more vertical space to be given to living walls, and their roofs can be greenspace as well, so that the building in effect does not diminish overall ground space given to plantings. Roof top tea gardens would be popular, creating elevated spaces from which to watch passersby, and other activity on the main level.

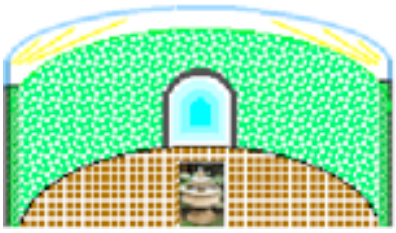


Illustration of a simple and small "greenhub" node. an intersection of 3 or 4 pedestrian passageways. It sports a higher

vaulted ceiling, painted a matte sky blue, with cove uplit with bright sunshine spectrum bulbs. Vertical surfaces are living walls. The floor is of brick pavers or cobble-stones, with a scattering of benches, flowerpots, and a central fountain. The lower vertical scale of connecting pedestrian walkways is seen.

Enter the polinators

It is amazing how many people do not realize that plants come in male and female also. Be that as it may, we do need to provide for plant pollination. Bees might be confined to agricultural areas, with only persons not allergic to their sting working in those areas.

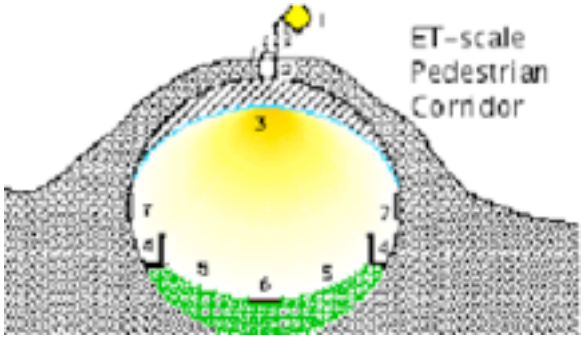
Hand pollination would be an unacceptable use of available manpower. Especially for agricultural areas, where similar plants are side-by-side, robotic hand-pollination equipment teleoperated from Earth where real labor costs are much lower, should be a priority area for research and development, with a lot of "spin-up" potential. In the meantime, we might concentrate on plant species that can be pollinated by hummingbirds. The sight of these tiny and beautiful creatures flitting to and fro in search of pollen syrup would do much towards making such urban relaxation spots all the more delightful. Might lunar hummingbirds slowly evolve larger subspecies? A hummingbird whose linear dimensions are 1.817 times Earth-normal for hummingbirds would weight as much on the Moon as our varieties do here.

We might make room for additional wildlife. Fish, talapia, small tropical, goldfish, even stream trout should mix well. But without adding in a mix of flying insects at great risk to serve as food, we'd have to feed them manually, or by automated fish-food dispensers.

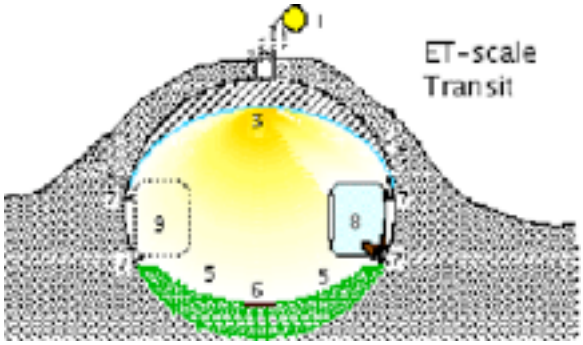
Squirrels and chipmunks can do much damage, but they sure are delightful to watch. The same is true of rabbits and other small mammals. If only neutered individuals were released into the settlement commons, and breeding stock kept strictly sequestered, runaway populations could be avoided. Humans evolved side by side with plants and animals. Sure, some individuals would sooner be without them. But how truly "human" are they? We need to go into space as the front wave for Earth life at large. We just have to be careful what species we bring along with us. But that's a whole new article.

If we are living, working, shopping, recreating, and traveling in pressurized spaces, there is no justification for any of these modules to be sterile, devoid of life. In our own cities, the boulevard is an icon for how pressurized roadways can be designed to contribute both to overall biosphere biomass, and to bio-diversity. Given the controlled climate, vehicles operating solely in pressurized environments can be open, roofless, and even open-sided. Of course, vehicles meant to operate at high speed would need wind-shielding.

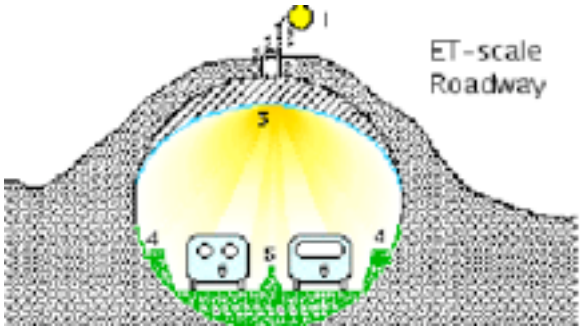
Various Larger Pressurized Passageway Options



KEY: (1) Sun, (2) fiber optic bundle sunpipe, (3) sky-blue sunlight diffuser (same pressure either side), (4) pedestrian walkways, (5) terraced plant beds, (6) gardener's path, (7) art & poster gallery



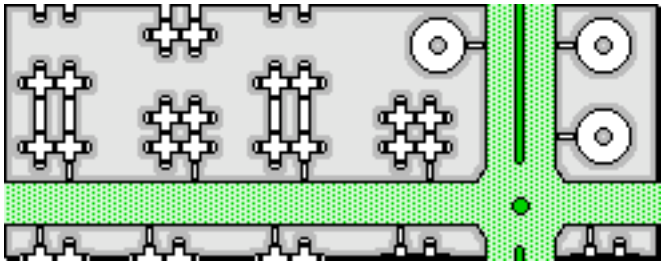
KEY: (1, 2, 3, 5, 6) as above. (7) wall-mount rail suspension system, (8, 9) bench seat transit car.



KEY: (1, 2, 3) as above. (4) living wall / hanging garden, (5) planter-topped divider, (6) vehicles.

In all of these connector examples, there is a place for vegetation, and the more place the better. It is more than a matter of morale, the comfort of mothering greenery against the stark sterile barrenness beyond the settlement airlocks.

It is a matter of always paying heed to the over-riding requirement to maintain a healthy and integrally functioning biosphere as a host to all other activities within the settlement hull complex.



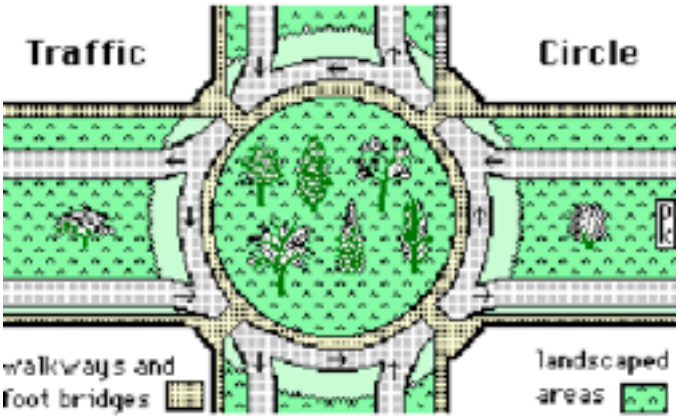
ABOVE: a sketch of how a residential settlement "block" grid could be laid out.

The Green represents the pressurized road grid and its significant contribution to the total biomass of this modular settlement biosphere.

One road is shown in boulevard fashion, with an expanded roundabout intersection centering on a tree & shrubbery inner circle.

The gray represents the open-to-vacuum regolith covered surface. Shown in it, are various modular residences, individually regolith-shielded, all opening onto the pressurized road grid.

This allows shirtsleeve travel throughout the settlement by pedestrians, bicycles, and electric vehicles.



More on the Settlement's pressurized road grid

There is considerable discussion of many aspects bearing on the topic of public places in the lengthy article "**Luna City Streets**" MMM #109, October 1997, pp. 3-11. This article has been republished in MMM Classics #11, pp. 61-69 - a free access **pdf** file download from:

www.moonsociety.org/publications/mmm_classics/

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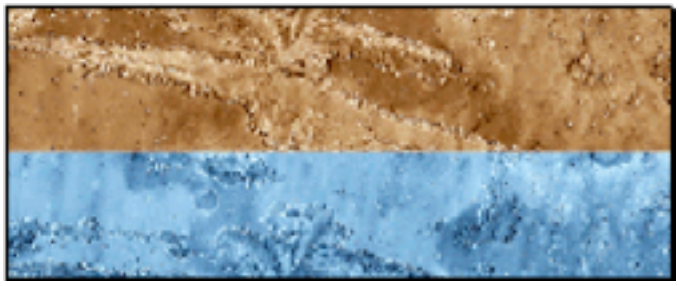
MMM # 203 - MAR 2007



How will Mars PioneersHandle Climate Shock?

Above, courtesy of a PhotoShop color inversion, we try to capture the "feel of Mars" as it looks, ***top.*** Somewhat like our Four Corners area: SE Utah, SW Colorado, NW New Mexico, NE Arizona - which can be quite hot on summer days. ***Below,*** the color inversion captures Mars "as it feels" - mirroring the full temperature range of Antarctica, a place very few would pioneer despite its fresh breathable air and abundant sea food. More, *below*

In FOCUS NASA Moon Plan gets an "F" as "Preparation for Mars"

In our MMM #191 DEC. 2005 editorial, "Dear Santa: a Moonbase made for Mars," we pointed out that if NASA's goal is to build a workable Mars Base and try it out on the Moon first, we would get several things advantagous to a moonbase that we might not otherwise get:

- **A life support system that went beyond umbilical cord style resupply, rescue, and repair**, but had to work without relief for extended periods of time, two years or more. This most likely would involve a considerable greenhouse food-growing operation, a system that could be easily dropped from a Moonbase-only program, given inevitable budget pressures.
- **A design that had to take "shieldability" into account** because the long stay times on Mars will demand such protection. On the Moon, in contrast, you could do without shielding if you rotated crews frequently enough.
- **A robust machine shop and repair facility**, because on Mars, one might have to fabricate a critical part if the last spare had been used.
- **Development of an adequate power system** not reliant on "eternal sunshine", which is something that would not be available on Mars. We might end up with a power system that would let us operate anywhere on the Moon, not just in the misnamed polar cul de sacs of "eternal sunshine."

Unfortunately, NASA seems to have dropped the ball on at least some of these considerations.

NASA has zeroed out the budget for all further advanced (biologically based) Life Support Systems, shutting down both the BioPlex at Johnson Space Center in Houston and the NSCORT project at Purdue. To save money in the classical penny-wise pound-foolish manner, NASA will rely on just in time supplies of oxygen and water to the Moonbase, just as it does to ISS. Only in the latter case, the Russians are there to come to the rescue when NASA is grounded. This decision makes it unlikely that a Moonbase will be staffed indefinitely without short or long interruptions. We all know that the "penny wise, pound foolish" approach is sheer stupidity. Of course, we can always blame it on the financial black hole otherwise known as the war in Iraq.

Some NASA moonbase designs show a modular ranch-style horizontal layout. But other mockups show the highly vertical, difficult to shield, Zubrinesque double tuna-can, in which at best, "sandbags" will be placed on top, is if the only direction of incoming radiation was from the Zenith. We are only at the paper stage as of now, so NASA may yet adopt the easier to shield horizontal approach. We predict NASA will take the cheapest "out," no matter what the consequences downstream.

No indications of a machine shop, repair facility, or fabrication shop yet. We'll have to wait and see.

NASA seems determined to take the easiest way out in developing a lunar power system. and that means that the agency probably will not predevelop a nuclear power plant for Mars to pretest on the Moon.

Is all this necessarily bad for Moon-buffs? We think so, but would be happy to be proven wrong.

1. That NASA has decided that the moonbase will **not** pretest systems intended for Mars, ***will cost Moon-supporters what support we had from the more thoughtful fraction of the Mars-enthusiast community.*** This "predesigned for use on Mars" formula was something Robert Zubrin insisted upon to earn his concessionary support for prior moonbase deployment. ***NASA having reneged, the cautious support of Zubrin and other Mars supporters has evaporated, probably for good.*** I think that is sad. As I pointed out in last month's issue, on the face of it, Moon-supporters and Mars-supporters have many reasons to be allies.

2. This means that it is up to the Moon Society and private enterprise to push the development of practical biospheric life support solutions. This is not all bad, as I strongly feel that NASA was taking the wrong track. Biospheric life support should be modular, growing apace with the modular physical settlement complex. The private enterprise/academia success with the Antarctic South Pole Station Food growth Chamber is something to cheer about and pursue further.
3. Whether or not NASA includes an adequate workshop and fabrication shop in its moonbase plans, we should include one in our Lunar Analog Research Station designs, following the lead of the Calgary Space Workers.
4. The Moon Society should also push and promote research and development of robust power storage systems adequate to manage the two week-long nightspan solar power drought on the Moon. This will allow us to set up shop wherever on the Moon it makes sense to do so on resource utilization grounds. Lunar industrialization is necessary if the Moon is to play its destined role in helping solve Earth's heretofore intractable and intertwined energy production and environmental degradation problems.
5. Passing the R&D torch to private enterprise and non-government funded societies and institutions is the only way to sidestep what it is becoming increasingly clear will be only a gestural NASA-led presence on the Moon. We will be there, in the sense that Kilroy was - if that means nothing to younger readers, don't worry about it. Baby Boomers and older persons get the allusion.

Unfortunately, there seems to be no way to insulate NASA projects or any other worthy government endeavors from the financial Katrina we are now experiencing currently and into the foreseeable future. On paper, the world economy is booming. In reality, accumulating debts are outpacing accumulating assets, and to this observer, it looks very much like a house of cards.

However, what is happening now in the private sector, especially with the COTS initiative, promises the development of private launch systems which could easily scale up to "do the Moon." On that silver lining note, we bring this discussion to a pregnant pause. PK

NOTE 12.05.2010: We wrote this 3 some years ago, and in retrospect, NASA's failure to design **"a moonbase meant for Mars"** has cost it enough support from potential allies, that the Obama Administration decision to cancel the Constellation Moon plan was a foregone conclusion.

One can protest that there was not enough money "to do it right." But in the end, "doing it right" is the only plan that makes sense. In fact, NASA never even tried to design its moonbase "for Mars" as the Bush plan clearly suggested it do. We cannot blame the pro-Mars community (Mars Society and Planetary Society) for urging the new administration to change course. We had our chance and flubbed it. Impatience always fails. The space advocacy community bears some of the blame, for failing to give constructive criticism. Many wanted the Moon period, not the Moon as training ground for Mars. Well, the result is, that for the time being, we have nothing.

In the end, we will do the Moon: other space agencies and commercial contractors. Have faith. **PK**

MODULAR BIOSPHERICS ON MARS

By Peter Kokh

While in general, what we have been saying in the past few issues about the importance of integrating biosphere components with the architecture of an outpost and settlement in modular fashion, applies to Mars as well. It makes sense to adopt an expansion strategy that will automatically grow the biosphere as the physical pressurized complex grows. Not to do so would be a prescription for disaster.

So why is no one else talking about "Modular Biospherics?" Simple. No one else is talking about expansion of outposts or settlements in the making. Be that as it may, the situation facing the pioneers on Mars will be less challenging than that facing early Lunans.

Note these advantages for early Martians:

- **Availability of CO2, N2, O2** - Mars air can be made on demand. The need to recycle CO2 from exhalation into fresh oxygen will not apply. However, it will be a good idea and any amount of plant life within the complex will help. The other tasks of keeping air fresh, cleaning the water, and growing food remain.
- **Reaching sustainability** may be easier since future Martians will find it much easier to make up for losses from leakage or deficiencies in plant production of fresh oxygen and processing of waste water.
- **The natural softer sunlight** on Mars can be easily intensified, but more importantly, it is available on a **more Earthlike 24 hr 39 min cycle**. Getting the plants through the nightspan will not be the challenge that Lunans must meet.

Agricultural advantages:

- **Vegetation** provides a sink for excess CO2 (but that is so on Moon also.) But on Mars, there is an **abundant external source of CO2** in the atmosphere, and much more frozen at the poles or locked into the rocks, but releasable upon heating. The Martian settlements will find it easier to have a much more generous ratio of tonnage of vegetation to tonnage of the human population.
- **This much greater abundance** of the volatile elements needed for life may make it easier for Martian pioneers to justify the food expense of **raising live stock**.

Rejuvenating Mars' Climate:

- **Note: we reject the word "terraforming."** What we need to do is not to make Mars "more Earthlike" (all we really know how to do is make Earth less Earthlike) but to restore the much warmer, wetter, life-friendly climate of the early Mars: "rejuvenescence."
- **As we slowly increase atmospheric pressure** by finding ways to permanently melt CO2 frost and ice at the poles, we can be developing plants hardy enough for partly pressurized areas, then finally for the Martian outdoors. - on Mars, biospherics will begin inside and then progresses to the outside

Check the article "**Redhousing**" in MMM #93 March '96, republished in MMM Classic #10

<MMM>

Bringing the Ocher Martian Outdoors In & Taking the Green Inside Outdoors

Overcoming the "alienness" of Mars
By integrating indoor and outdoor elements
To visually integrate both environments

By Peter Kokh

A home furnishing and decorating goal growing in popularity, particularly but not exclusively in warmer, sunnier climes is "bringing the outside in, and taking the inside outdoors." For example, a home with a window wall and a patio beyond, will have the floor/ground space on either side finished with the same tile, patterned concrete, etc. There will be a visually uninterrupted flow of green foliage on both sides. Similar indoor-outdoor furniture will be placed on both sides. The idea is simple: the outside space should appear to be an extension of the adjacent indoors; the indoor space an extension of the outdoors. In the process, the boundary between home and homesite, between artifact and nature is blurred. The uplifting effect on the spirits of the home dwellers is significant and satisfying.

Future homesteaders on the Moon and Mars can do something similar, translating the above devices into the environmental languages of each world. Here we look at the opportunities before future Martians.

Window walls are not a near term: the pressure differential and the need to maintain radiation shielding create quite a challenge to this concept. However, the device of periscopic picture windows can be tweaked to create an illusion of a similar situation. A neat architectural choice would be to place any airlock so that anyone entering or leaving will do so in plain view out this picture window. This would make the outside area in view an obvious area for a "patio" treatment.

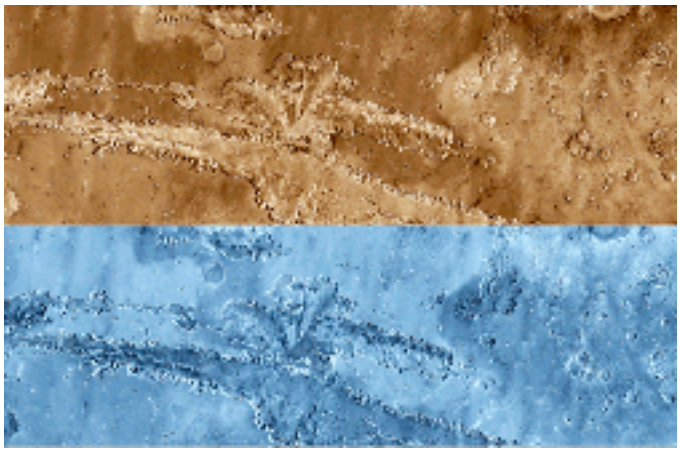
The same choice of Marstone pavers and/or tiles made of Martian materials can be used on both sides to suggest an uninterrupted flow of the homestead (or hotel, etc.) floor into the outdoors. Similar sculptures and other accessories could be used on both sides of the divide. Iron furniture with or without a pre-rusted surface could be used, a bench at least.

A Zen type stone and sand garden is another feature that could grace these two diverse juxtaposed environments. As for plants, faux plants made of stained glass elements could grace the patio. Long term, there are more exciting options: "Mars-hardy" plants bred to handle the slowly increasing air pressure of the slowly warming atmosphere. While that is not in the cards near term, there is no reason to delay experimentation now, here on Earth, by breeding various arid zone terrestrial plants to survive in increasingly more Marslike conditions. See the article "Redhousing" cited in the previous article. Once we are on Mars, "redhousing" may become a very popular hobby among the pioneers, not content to just wait, wanting to help make it all happen.

To ramp up the possibilities, a well-sunlit quartz-domed (UV safe) "patio" area would be an environment transition zone between pressurized indoors and the raw outdoors. It could be lightly pressurized to 10 times Mars normal, 1/10th Earth normal. One would enter this "arearium" via an airlock with only a light pressure suit. This would serve as a "redhouse" for plant breeding experiments, blurring the inside/outside barrier. **<MMM>**

Acclimatization Shock on Frontier Mars

By Peter Kokh



Mars as it looks, top
and as it feels, bottom

Mars is *cold!* **This image is online at:**
http://members.aol.com/tanstaaflz/vallesmarineris.gif

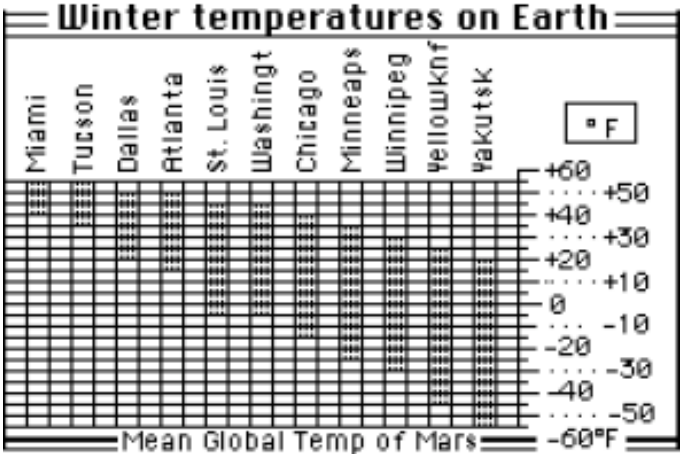
Being Honest About the Cold

From MMM #103 March '97 "Tempering Enthusiasm for Mars as The Next Human Frontier with Personal Honesty"

"A cherished dream dies hard. We have known for a couple of decades now, that the real Mars is a much colder, drier, thinner-aired world than the one we used to dream of colonizing, than the Mars of Lowell and Clarke and Heinlein and Bradburry, the Barsoom of Burroughs.

"We had ourselves prepared for thinner air, say that of Earth's high mountain plains 20,000 feet up. Alas, Mars' air is more comparable in pressure to Earth's at 125,000 feet, more than four times the height of Everest. We had ourselves braced for cool Martian summer days in the 60°s (F) and winter nights perhaps the same number of degrees below zero (F). But Viking meteorological stations showed a year in, year out pattern much much more bone-chillingly cold than that. *Mars has no Florida.*

"We still don't quite believe it. For the cold is "invisible" – there is no surface ice or snow – away from the polar regions – to give us a clue. We look at the Arizonesque scenery and we expect Arizonesque temperatures. Mars *looks* seductively tolerable."



Who will find Mars inviting enough to pioneer?

Most of us can put up with dismal conditions for a while, if we know that things will change in the foreseeable future. Those who by birth or by life-style decision live in sunny warm climates still must experience periods of unusual storminess, drought with fire hazard, etc. But those who live in colder snowbelt areas are somewhat hardened to seasonal changes, and many "join what they cannot beat" and learn to love winter. We northerners have to bear up under occasional blizzards and with frequent sunless cloudy periods sometimes two weeks long. Those with an internal sun flooding their lives with sunshine regardless of the weather, do best. But for all of us, we know that dismal conditions will sooner or later change for the better. Not on Mars!

How we do the indoors is critical

How will pioneer Martian settlers cope? Spacious interiors lusciously green with vegetation, and pools of sunshine-like over-illumination will work wonders on the soul. So these things are important. The longer we house ourselves in sardine cans, the sooner the settlement will catastrophically implode with general mental illness.

But will this be enough? The deceptive warm colors of the Martian landscapes hide an ice-blue reality. Even near the equator, only a handful of days will have highs well above freezing ("shirtsleeve" temperatures will be exceptional) with 22+ Earth months to go before the next warmup.

Homestead design options which allow the pioneers to "bring the outside in, and the inside out will also help. Homestead attached "redhouse" gardening spaces will further psychologically buffer that invisible ice-blue bone-chilling, life-sucking cold.

Selecting the Pioneers for Mars-hardiness

Volunteers from cold desert regions, even from arctic and subarctic tundra regions, will make for a significantly hardier stock of immigrants. Even so, the most arid desert is more lush with vegetation than Mars, and tundras are abloom with low-lying plants and flowers come spring. Spring will come to Mars only in terms of lighting conditions, astronomically, without signaling the awakening of life as it does on Earth.

Native-born Martians, even the first generation of them, will take the Mars climate for granted, even though they will be familiar enough, second hand through a video screen, that conditions on Earth are different. If the settlement is to survive, we absolutely must but childbirth on the fast track. If that means that women recruits board the ship to Mars pregnant, then we must do so and all considerations of caution become trivial.

There will always be fresh immigrants to Mars, but the quicker we can reach that state where the Earth-born fraction of the settlement population is a minority, the more assured we can be that settlement on Mars will truly "take." If, out of timidity, or moral pretense, we defer childbirth, then all we will succeed in doing is building a ghost town. As strange as it may seem at first impression, only Martians can truly settle Mars. The rest of us Earthlings can only make a pathetic attempt. None of us will have the right stuff. Only native-born Martians will truly have what it takes.

If this attitude sinks in, we have a chance. Human civilization will have taken root on Mars. <**MMM**>

Mascots on Moon & Mars – "Pixel"

A stray cat finds its way to the Mars Desert Research Station and stirs up a firestorm!

By Peter Kokh

Editor's Opinion Piece: Pet lovers and non-pet lovers cannot see each other's viewpoint. It's as if we are two kinds of human, or, as we animal lovers think, human and not-quite human. **Fact:** Humans evolved side by side with animals. Bones of domesticated wolves and dogs have been found in the relics of campsites dating back 100,000 years. In comparison, cats seem to have been domesticated by the Egyptians just 6,000 years ago. The upshot is that wolves became dogs as our ancestors became fully human, together, in each others' presence, possibly with results that could not have been achieved separately. In that light, nonanimal lovers would seem to suffer from some kind of deficiency, perhaps via lack of reinforcing experiences. Sorry if I offend non-animal loving readers, but this is a subject on which I prefer not to pull my punches.

In "The Greening of Mars" Lynn Margulis and James Lovelock allow no place on Mars for animals. They give their reasons, but these are not reasons at all, only challenges to be overcome. The case histories of the mental health of both children and seniors who do or do not have animals in their lives are quite telling. Mars without animals will be a people colony, but not a human one. If Earth were ever to be destroyed and only an animal-free Mars survive, the humanity of humankind will have perished. – PK

The MDRS Email Salvo

Per Robert Zubrin's direction, the cat is NOT to be returned to the Hab because it is not in sim [can't wear a spacesuit]. We have to add more traps and poison (unless someone has a better idea). I'll see if I can come up with more sticky traps.

–*Tony Muscatello*, MDRS Program Manager

Pixel seems have to become THE Mascot of MDRS. The very odor of the cat may ward off rodents wishing to board MDRS. [snip] The cat is good for repelling rodents, and "damned good" for Crew Morale. Methinks kitty gets hungry enough, the ancient instincts kick in and putty-tat goes and kills a mouse to eat. No chemicals, just old fashioned hunting. [snip]

– *Peter Gray*

 This is an ongoing discussion and some progress has been made but not finalized. I'm a cat lover.

– *Maggie Zubrin*, Mars Society Executive Director

[The editor does not want to give the impression that Dr. Zubrin is an animal hater. Maggie has horses kept at another property, and I have seen a photo of Robert obviously beaming, watching his daughter Rachel ride one of the horses. Rather, this is a debate on how animals can fit in, given the starting presumption that they don't.}

Previous treatment of this subject in MMM
MMM #8 Sep. '87 "Animal Life in Settlement Bio-spheres" followed by "Colonists' Animal Life Quiz" – both republished in MMM Classic #1 , pp. 23-24 (see p. 2 col A for download locations). Also online at:
www.asi.org/6/9/3/2/008/animal-life.html

We do not want to butt in on deliberations About an Animal Policy for MDRS. We might have to humbly retreat when we deploy a Lunar Analog Station! However, we must make these observations: The Mars Society could announce that only those non-allergic to pet hair and dander need apply for crew assignments, and then keep the cat (and any future successors.) Or animals can be summarily banned.

Now that won't work, because MDRS has long been infested with mice and occasional desert rats. The many openings in the hull make it all too easy to enter. So there will always be exposure to animal hair and dander. And the odor of Pixel may remain for some time.

The Mars Society can either live with this reality or choose to do something effective about it. That does not simply mean eradicating the present rodent population from their many hiding places. It means, first of all, denying access. Otherwise they will simply return. In that light, "a cat out of sim" doesn't seem that bad. Morale wise, it can be a big boost for those crewmembers who have left beloved dogs or cats at home to come here.

Space group integrates animals into their vision
www.calgaryspaceworkers.com/animalsinspace.html
"Part of the Calgary Space Workers agenda is to demonstrate the subsistence and human-animal interaction needs in a lunar habitat analog situation. Lynn Gustafson, owner of a beautifully-run zoo just north of Calgary hosts some animals that might be expected to find a place in humanized outer space. Human interaction with animals in space is also therapeutic and therefore some desired animals may not be subsistence related. It is important to realize that it is easier to take a dozen eggs to space, have them hatch and then have the hatchlings mature and lay eggs and so on to produce both the chicken and the eggs for subsistence purposes. This is called "bootstrapping" and is like using computers in the manufacturing of more advanced computers. "Humans are more relaxed and enjoy the company of animals as animals are not as susceptible to the stresses of daily activities."

A Mascot on real Crewed Mars Missions?

Dog, cat, or something else? A pet that interacts with humans would be best, with dogs better at that than cats, but requiring more care. Any animal would boost morale. The inconvenience would be worth it! <**MMM**>

~~Killing Time~~ *Productively* on the Way to Mars *and* on the Return to Earth

By Peter Kokh

Background: Apollo astronauts complained about the long boring 3 day trips from Earth to the Moon and then again on the way home.

We wrote about the problem back in November, 1989.
"Wanted" MMM #30, republished in MMMC #3 pp. 55-7

WANTED: Split personality types for Mars Expedition
Besides being willing and able to leave Earth, family, and friends behind for three years or more, must *for the trip out and back*, have a high tolerance for sensory deprivation and thrive on boring routine tasks; and, at the same time, *for the period spent on the surface,* must be thrill- and challenge – positive, keenly attuned t o external situations with all their unpredictability. If you are such a Jekyll-Hyde combination, please send your resume to:

- Mars Expedition Personnel Office
- Mars Training Camp, Spitzbergen [Svalbard]

Continued:

"For as long as the era of chemical rockets lasts, interplanetary journeys to Mars or the asteroids, will be long tedious affairs that will be very trying for the kind of people ideally suited for the kind of life that awaits them at their destinations.

"This presents us with a choice. We can either look for persons with such chimeric personality combinations as suggested above who will perform reasonably well under such diametrically opposite circumstances, *or* we can start now to plan ways to structure the times of transit to better fit the personality traits of those best cut out for the exploratory and/or rugged pioneer life on the untamed worlds of their destination".

"First, we must recognize that the trip out and the trip home are radically different in the deep psychological challenges they present. Outbound, the crew will be filled with anticipation. Homebound, they may experience both anticlimactic letdown and an impatience to get back home."

Suggestions from this Earlier Article

Outbound Leg

- Equipment Assembly: Items manufactured on Earth for use on the Martian surface, after all parts had been tested and checked individually and in verifying assembly, could, if they would travel more compactly unassembled, be disassembled for the trip out.

  En route, they would be put together in a Big Dumb Volume inflatable module, launched uninflated and compacted. Ultra-critical equipment can be shipped preassembled, with less sensitive equipment and backup equipment shipped "knocked-down" (KD) for assembly en route.

  The assembled equipment would have to fit into the fixed volume part of the landing craft. This limits this option to compact objects and compact subassemblies.

  Is this "make work?" I would not be so quick to dismiss the idea so casually.

Return From Mars Leg

- **Preliminary chemical & physical analysis of samples** being returned to Earth, along with some building materials processing experiments.

  Surface samples could be separated into two quota portions, those held safe and untouched for labs on Earth/LEO, and those on which preliminary analysis and experimentation can proceed en route

  Trained geologists, mineralogists, chemists, micro-biologistss, exobiologists and other scientists will be essential to the crew.
- **Debriefings and reports,** while experiences are fresh, can be followed by round table discussions of how the success of a follow-up mission could be best enhanced (new equipment, added tools, improved lab facilities, mmore comfortable housing, more amplelife support, better fresh food growth chambers, greater menu diversity, etc.; better training; additional talents to be represented in the crew mix, etc.)

  Sensory and other impressions can be set to canvas or disk by those on board of artistic, poetic, or philosophical bent.
- **EVA Sports:**

  To NASA's abject horror, no doubt, there is a very real opportunity for totally new tethered-EVA sports outside rotating structures.

  By shortening a tether to the hub, one would advance on the structure. Conversely, by paying the tether out, one would fall behind - simple conservavtion of angular momentum.

  Using such maneuvers in tag matches might be risky, but rally-type events in which one faced the clock, one at a time, to land first on a forward perch or tag ring, then on one to the rear, before returning 'home', all by manipulating the effective length of the tether, could provide healthy, adrenalin-racing sport. This could be welcome stuff to a crew chosen to be optimally tuned to the pace of activity of the Mars surface part of the expedition.

  Sports Media coverage of such "Space Games" might draw big audiences and could work to get across the idea that we can, if we but try, make ourselves at home in Space! Of course, there will be the critics who decry money spent on making such options possible. Providing the necessary equipment by Private Enterprise sponsors would cut that drivel talk short.

  When such sport is embraced, either on the sly or with reluctant official consent, we'll have come a long way towards making the space lanes home. We recommend it for the way back. That way, should an injury or mishap occur, the ground mission on Mars will not be compromised.

"Dangle-Jectory" Rallye: From A to B to C to A

(The above illustration presupposed a three-armed rotating structure, should three craft travel to Mars together, not necessarily the likely option.)

What else can keep our Martian Explorers productively busy on the long tips out and back?

Outbound & Inbound:

- **Continuing education courses**, in their line of expertise or outside it, to develop other talents & interests, whether helpful only on Mars, only on Earth, or both
- **Observations & measurements** of the solar wind and other astronomical objects and phenomena even if these observations could either be done just as well from LEO, or if not, by robot probes.
- Data mining & digesting latest robotic feed news. It is a sad commonplace that budget pressures have forced NASA to prematurely halt data analysis from various missions leaving potential discoveries undiscovered.

Outbound only:

- **Backup Expertise Training:** Learn as much as possible about each other's areas of expertise to provide talent redundancy should a crew member be injured or sidelined in any way.
- **Self-schooling** in useful areas of talent and expertise not represented in any of the selected crew members

Return bound only:

- **Expressing their recent experiences** and fresh memories in painting, poetry, essays, song
- **Comparing notes** as the individual crew members each wean themselves from preoccupation with Mars and begin to focus on homecoming events and their anticlimactic afterlife on terra firma. Many of the Apollo astronauts experienced "anticlimax" effects. After all, being on Mars (or the Moon) is a hard act to follow!
- **Webcasts** & podcasts to students on Earth about various aspects of the just completed mission. (The Interplanetary Internet [InterPlaNet (IPN)] will be in place in 2008.) These broadcasts won't be truly interactive until the crew is much closer to Earth. Even at a mere million miles out, the round-trip signal lag will be about 11 seconds. Prior simulations could suggest at what distance live conversations can effectively be maintained. This would be a near zero-budget chapter experiment. We suggested this in MMM #131, Dec. '99, p 6. "The COLLOQUIPAUSE: end of conversational space" (republished in MMMC #14)

Recommendations: inflatable "elbow room"

Provision of inflatable "elbow room" space on both legs is vital for morale and proper exercise. Simply designing in space that would make it possible to take "a walk" would be of immense benefit. Whether for exercise, to "cool off" tension or rising anger, of for "constitutional" purposes does not matter.

But space for individual exercise and perhaps for small team sports would really top it off. Health is essential not just for morale, but for productivity once the crew arrives on Mars.

If the return crew ship is different from the Mars crew lander, the inflatable module for the outbound trip could be designed to be easily deflated, compacted, and stored for entry through the atmosphere to landing on the surface of Mars. It could then be removed from the lander and transferred to the homebound ship. Or both craft could have their own built in detachable inflatables.

Our scouts, no matter how exemplary cases of the "right stuff" they may be, cannot be expected to bear up in cramped conditions for many months at a time, either outbound or returnbound, without severe strains on interpersonal relations that could adversely affect the mission's success, and without suffering from low morale and depression. Unless we are going to put them to sleep for the duration, an old science fiction trick that we are not able to pull off at the present time.

It's not a simple proposition, however; at least, not if artificial gravity is to be provided at the end of a rotating tether with cargo etc. at the opposite end. In this case, the inflatable structure must be in line with the tether so as not to displace the crew module proper off center. The inflatable could be bottom-mounted, side surrounding, or top-mounted. If an aerobrake shield is used for Earth atmosphere reentry, the inflatable could be in the form of a torus that sits on the rim of the shield as already suggested. An aerobrake is illustrated below.

http://www.spacephotos.com/catalog/images/detail_phototheque/S00308.JPG – credit

A torus structure, while it is more difficult to construct, could be ideal, providing a walking/running track. It could be top-mounted with the tether through the donut hole, bottom mounted around the fuel tanks and just above the edge of the aerobrake shield as in suggestion (c) above, or simply surround the crew module in the 'donut hole.' (suggestion (a) above. All of these options will require design and engineering ingenuity. We have the "right stuff" to do that, don't we?

Yes there would be a weight penalty. But I posit that we will owe our returning heroes this morale-boosting "luxury." They will already have deprived themselves of too much for too long.

Recommendations: Artificial gravity

On the way out, artificial gravity is essential. Our scouts must be in tip top physical shape on arriving on Mars, without having to rest up for a while, wasting a few weeks. The gravity level should be 3/8ths earth normal, the gravity level of Mars.

On the way back, an initial Mars level gravity should be increased gradually to full Earth normal over the months of the return, to put them in tip top shape when they next set foot on Earth after an absence of as much as three years. <**MMM**>

Terraforming Resources for Mars

Rejuvenating Mars Might be both easier and more troublesome than we had dared imagined

By Peter Kokh

Source: This Week in SCIENCE, Volume 315, Issue 5811
www.sciencemag.org/content/vol315/issue5811/twis.dtl

The bulk of Mars original generous endowment of volatiles, atmosphere and water, may not have "escaped" into space.

The New Good News

We have realized for some time now, that early in its history, **Mars was once wetter and warmer, and possessed a denser atmosphere than it has today.** It was natural to assume that this early thicker atmosphere, being constantly battered by the solar wind and held in place by Mars lighter gravity, evaporated into space.

However, Barabash et al. (p. 501) (report dated January 26, 2007) find that the escape rate today for gases in the martian atmosphere is very low, based on measurements from the orbiting Mars Express spacecraft. Propagating these rates backward over a period of 3.5 Gy would result in the removal of 0.2 to 4 mbar of CO2 and a few centimeters of water. Rather than having left the planet, CO2 and water could instead be locked away beneath its surface.

Implications for "terraforming" rejuvenating Mars

The early "easy" climate improvement projects still seem the right way to start. Dust the polar caps with carbon soot, derived from the atmosphere itself, to decrease the planet's albedo (sunlight rejection capacity) and heat the polar water ice/carbon dioxide ice caps to free the carbon dioxide. This just makes permanent a process that happens at each pole each summer. Frozen CO2 evaporates but only to refreeze over the opposite (winter) pole. By using the carbon soot dusting technique, we will prevent refreezing and thus permanently increase the global atmospheric pressure, which in turn will moderately warm the planet, again, on a global permanent basis.

Now we know that we do not need to follow this initial improvement up with a period perhaps centuries long in which water-rich comet chunks would be redirected to impact the Martian surface. That would be a risky proposition, not only increasing seismic activities, but bearing the risk that an errant ice payload might take out a key settlement!

We can skip all that! A favorite of science fiction from Edgar Rice Burroughs John carter on Mars series right through the ghoulish film "Total Recall" is the "atmosphere plant" which takes martian soil in and spits volatile gasses out.

1. We almost certainly have enough CO2 locked in the Martian rocks that can be released through heating by solar concentrators, whole farms of them! This process would be slow and gradual, at a pace at which increasingly more Mars-hardy breeds of redhouse-raised plants could sooner than expected survive on their own outdoors.
2. Most of Mars water could be preserved in aquifers, some of which might be deep enough (as on Earth, Mars crust is likelier to get warmer with depth) to have

remained permanently liquid. That means that once the atmospheric pressure and temperature were great enough to support liquid water, underground reservoirs could be pumped up to surface basins. The deepest basin on Mars, where the air pressure will always be highest, is not in Valles Marineris, nor in the suspected northern ocean basin, but in Hellas. Hellas is one feature that has survived from pre-orbiter mapping to the present day. Called a planitia (rather misleading) it is the deepest and largest impact basin on Mars, and unlike similar basins on the Moon, not subsequently (post-impact) filled with layers of lava sheets.

The Good, Bad, & Ugly of Accelerated Climate Change

If the new calculations and findings hold up under scrutiny, and if future deep drilling confirms extensive and voluminous subsurface water aquifers, Mars could become a much friendlier place within the first century of the onset of a determined settlement effort.

Sloppy Mars

But forget about the progression **"Red Mars, Green Mars, Blue Mars."** First of all, Mars will get greener and bluer at the same time. More unwelcome is the news that **Muddy Mars** will come first.

With the onset of natural or chemical-induced precipitation (rain and snow), Mars' unfixed soils will be subject to substantial erosion, without vegetation ground cover which can only now first begin. It will take some time before vegetation starts to win battles with erosion.

Redhousing, now, to the rescue

The sooner settlers, following the lead and improving on the work of those terrestrial fans of Martian settlement who abandon the comfort of cheering from the of their demotivating sofas and roll up their sleeves and get their fingernails dirty by attempting to take arid-zone hardy terrestrial plants and breed them into ever more Mars-hardy strains, via "redhousing." the sooner we will get a handle on the mud.

We need to have a diverse variety of fully Mars-hardened plant varieties ready to plant as the first rains start to fall - if we are going to win the battle with mud and erosion. [Check the article "Redhousing" in MMM #93 March '96, republished in MMM Classic #10]

The Upshot: Mars in shirtsleeves? Not quite

Sooner than expected, Mars could become a much more benign, and attractive world than it is now. This requires both industrial projects like atmosphere plants and deep aquifer tapping, but also horticultural projects, breeding the plants that can thrive on the new "young again" Mars.

But this new Mars will not let settlers go outdoors with the same minimum of protection we are used to wearing. The atmosphere will be thicker, but still mountaintop-thin by our standards. UV dangers will be high. We may need light pressure suits and oxygen masks, and more than "sunscreen lotion" protection from UV. That said, the new Martians will begin to develop an abundance of outside sports, sporting, and recreational activities. And the climate will still be cold by Earth standards, with doubly long seasons. But in this born again Mars, the settlers will begin to truly thrive. Our human exclave will become permanent.

<MMM>

The Large Millimeter Telescope in Mexico

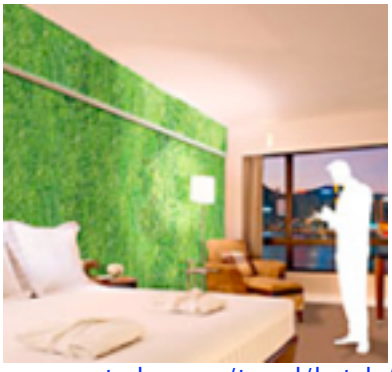
At Volcan Sierra Negra, center, just SW of Mexico's tallest peak, Pico de Orizaba, right, what may become the World's most important astrophysical telescope nears completion, with 60% funding by Mexico. This could well be a prime site for a dedicated Near Earth Asteroid hunter telescope, 900 miles west of Chicxulub Crater, site of the dinosaur-killer impact. For full sky coverage we need Southern Hemisphere sites as well.

MODULAR BIOSPHERICS

By Peter Kokh

I. Living Wall Systems, Continued from MMM #201

We recently found this excellent example to share.



[credit: Phillips & Co.]
A wall that breathes: Envisioning some backlash against high-tech surroundings, designers conceived a back-to-nature hotel room with a lush "living wall" of grasslike vegetation. The wall, with a built-in watering and lightingsystem, would serve as an air filtering device, too.

www.usatoday.com/travel/hotels/2005-05-05-hotel-of-tomorrow_x.htm

III. Toilet-equipped Habitat & Activity Modules - Wolverton or alternate black water pretreatment systems

The organizing idea of "Modular Biospherics" is to distribute biosphere maintenance functions throughout a growing modular physical complex. This philosophy obliterates the "single point of failure" biosphere catastrophe scenarios to which any centralized system or complex of systems would be inherently vulnerable.

It is also a biosphere architecture that grows naturally as the physical complex of the outpost/settlement grows. The size of any "problems" that must be tackled in central, or neighborhood treatment facilities is greatly reduced. Modular Biospherics greatly reduces both the scope and the frequency of "growing pains" crises.

By distributing are and water treatment systems, biosphere maintenance becomes a democratic process: it is everyone's concern, and the immediate local consequences of neglected systems affect most those who are guilty of the neglect. We take Earth's immense biosphere for granted (up until recently, anyway.) On the Moon, the health of the minibiosphere of each settlement complex must be everyone's business or catastrophic failure will only be a matter of time, and will come sooner rather than later.

Living Wall Systems are designed to refresh air throughout the complex, with only local maintenance needed. Stale air sets off personal mental alarm systems rather effectively.

But we must also treat waste water, both gray (sink, shower) and black (toilet wastes: urine and feces) locally. Not only does this give us a further opportunity to "grow fresh air" within ever module that has a toilet system, but it helps pretreat blackwater at the source of the problem, greatly reducing the treatment burden to be handled in a centralized, or, better (in tune with our "as the settlement grows" philosophy), in neighborhood facilities. Wastewater treatment systems that "grow clean water" should be in every habitation and activity module: not just in residential quarters, but wherever people work, shop, go to school, play, or are entertained.

Many systems have been tried, some of them quite ingenious, mostly in rural settings that lack central water treatment systems. Some of these systems require an exhaust to the exterior atmosphere sink to handle the odor problem. As we can't exhaust stinky air outside on the Moon, at least not routinely, many "composting" toilet systems that work perfectly well on Earth will not pass muster on the Moon. The odor problem must be handled on the inside! That creates an extra burden, which to ane one with the proper attitude, translates to an inviting" challenge," the kind of incentive that spurs ingenuity to greater achievement.

The Wolverton gray water system is one option that has worked for nearly 30 years in the home of retired NASA environmental engineer, Bill Wolverton in Houston.

KEY: 1 side- or wall-flush toilet; **2** blackwater tank with microbes to break down solids & destroy pathogens; **3** inert filter with irrigated soil; **4** plants rooted in wet soil mixture; **5** effluent water is 95% pretreated, ready to water plants In the greenhouse and elsewhere. - illustration by the author.

There are undoubtedly other systems systems, but Dr. Wolverton's well-tested system sets the bar against which other systems must be measured.

The system above handles the load imposed by two people. We need to know to how many people-hours per day that translates. Are they home all day, everyday? Or half the day most days? Blackwater systems must be rated in people-hours capacity if we are to size them to the daily loads of other activity modules such as work spaces, offices, schools, shopping areas, etc.

If we can someday deploy a modular lunar analog research station facility, we will want to try a variety of such systems in order to verify how well they work, and how they compare on various performance parameters. This fits the goal of such an analog facility to demonstrate the technologies needed for actively growing lunar outposts and settlements. There may well be a comercial component of such experimentation, with various manufacturers contributing systems for the various modules in a high-stakes game of make or break.

The penalty of not aggressively developing a full suite of modular biospheric technologies is clear. The planned "visitable" (but no longer intended to be permanently manned) outpost must be constantly resupplied from Earth, or by a very wasteful program of local throwaway oxygen and water production. Engineers and architects of modules may prefer to "keep it clean, and sterile" but our job is to create a "biosphere flywheel" that largely maintains itself with a modest amount of monitoring. We need to keep dependence on resupply from Earth to a minimum, if we are going to progress to the point where those on the Moon can survive politically or economically driven cutoffs of support, be they temporary or indefinite. This must be our goal! **<MMM>**

Myth 1) "Mercury is too Boring"

On first hearing, the suggestion of human settlements on the planet Mercury seems nothing short of ludicrous. Virtually every astronomy or space travel textbook we have read describes the planet as utterly hostile to human life. Generally described as a slightly larger Moon, Mercury is often ignored as being either too difficult to reach, too dangerous to live on, or just too plain plain. Let the unmanned probes go there. After all, Mars is more interesting. It depends on just what you are interested in.

Any reasonable concept for human expansion beyond Earth must include hum drum activities like mining, energy production, manufacturing of common and exotic items, and the transport around of people and their stuff. This will be the case wherever we go. If we are wise, those of us who truly want to see bona fide human expansion into space - as opposed to mere exploratory visits - will weave the common, mundane issues into our planning. On that basis, we will do well to consider colonization of Mercury.

Mercury is one of the most energy-rich planets in the Solar System

Energy is the key to whatever we want to do in space. Historically, we have always sought out cheaper energy sources and have experienced economic booms when they are developed. So it will be in space. On Mercury, the energy situation is analogous to taking a shower under Niagara Falls: we'll most likely never use all of the available energy. In fact, if energy were the only criterion of concern, we would not even bother with Mars. With the possible exception of geothermal energy, Mars is wantingly poor in energy sources, having only 1/20th* the solar flux available on Mercury. [*solar flux varies with the inverse square of the relative distance from the Sun.]

Photovoltaic and thermodynamic power systems operating in Mars orbit would still have only 45%, on average, of the solar flux to work with as is available on The Moon. Systems operating on Mars surface would have even less owing to the atmospheric effects. While would-be Mars colonists can be assured of having enough energy with which to survive, they will always be at the bottom of the well looking up, when it comes to Mercury.

[**Ed.** Mercury and Mars may be on a par, however, when it comes to uranium and thorium sources for fision power.]

Material resources on Mercury are known to include all the same base elements found on the Moon: Silicon, oxygen, iron, aluminum, titanium, sulfur, calcium, potassium, and magnesium have all been identified as constituents of minerals that remain stable in Mercury's thermal environment. We do not yet know the exact details of abundances or distributions What we have learned has been gathered from interplanetary distances using spectrographic analysis. This implies the resources mentioned above must be in substantial supply if they can be detected from such a great distance.

Importantly, hydrogen is also a proven resource on Mercury. We know that hydrogen is available as a constituent in Mercury's atmosphere from both space craft observation and spectrographic analysis. Properly described as an exosphere, the abundance of hydrogen there is paltry by almost any standard. Still, it is a constant supply as it is derived from solar wind sources and is available over the plate's entire surface. Superconducting ion 'scoops' deployed over large areas and running constantly can collect substantial quantities of hydrogen. Liquefying the hydrogen is an energy intensive proposition, but Mercury had the energy.

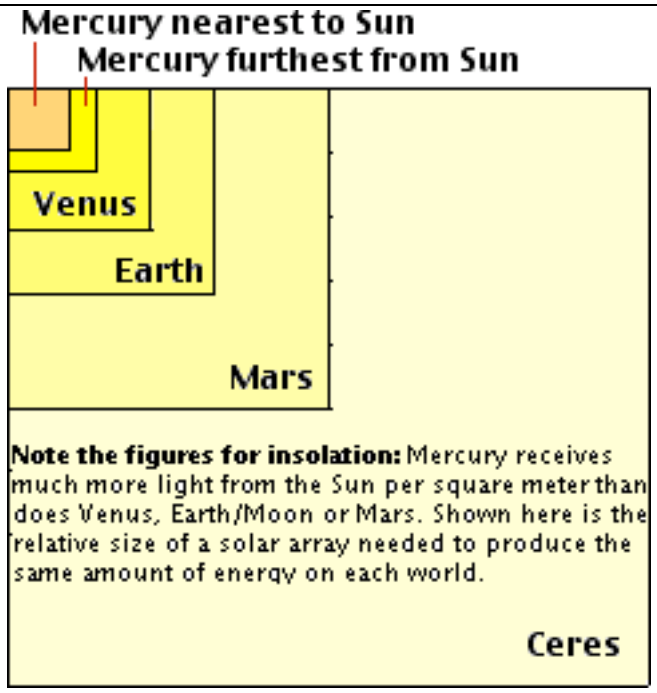
The importance of this hydrogen, diffuse as it is, cannot be overstated. First it means that people on Mercury are assured a self-sustaining source of water, even if the data indicating water ice at the poles is wrong. Second, it assures the ability to provide hydrogen fuel for flight into Mercury orbit, and, eventually, into interplanetary trajectories. This favorably alters the economics of flight to and from Mercury in a big way.

[Ed. Note that Mercury also possesses **abundant oxygen reserves** locked in the minerals of its crust, for use as a fuel oxidizer.] Industrial processes involving hydrogen as a feedstock, or as a reagent, also become possibilities.

[**Ed.** Does the regolith on Mercury adsorb solar wind protons (hydrogen nuclei) as is the case on the Moon? **The solar wind** is stronger at Mercury than at the Moon. On the other hand, Mercury's global magnetic field may lower the number of solar wind particles getting through. The upshot is that we need a surface probe to find out.]

How does Mercury Stack Up?

M	Merc	Venus	Earth	Moon	Mars
Mass 1024kg	0.33	4.87	5.97	0.07	0.642
Diameter km	4879	12104	12756	3475	6794
Density kg/m3	5427	5243	5515	330	3933
Gravity m/s2	3.7	8.9	9.8	1.6	3.7
Escape Vel km/s	4.3	10.4	11.2	2.4	5
Day hours long	4222	2802	24	708.7	24.7
Sun Dist10(6)km	57.9	108.2	149.6	0.384*	227.9
Insolation avg	6.68	1.91	1	1	0.43
Orb. Period days	88	224.7	365.	7.3	68.7
Orbit Speed km/s 4	7.9	35	29.	8 1	24.1
Orbit Inclined	7°	3.4°	0°	5.1°	1.9
Orbit Eccentric	0.205	0.007	0.017	0.055	0.094
Axis Tilt	0.01°	177.4°	23.5°	6.7°	25.2°
Mean Temp °C	167	464	15	20	-65
ATM Pressure bars	0	92	1	0	0.01
Number of Moons	0	0	1	0	2
Magnetic Field?	Yes	No	Yes	No	No



Gravity: while smaller than Mars, Mercury is much denser, and has a similar level of gravity.

Surface area varies with the square of diameter. Mercury's surface is 2x that of The Moon but only half as large as Mars' (or of Earth's total continental area.).

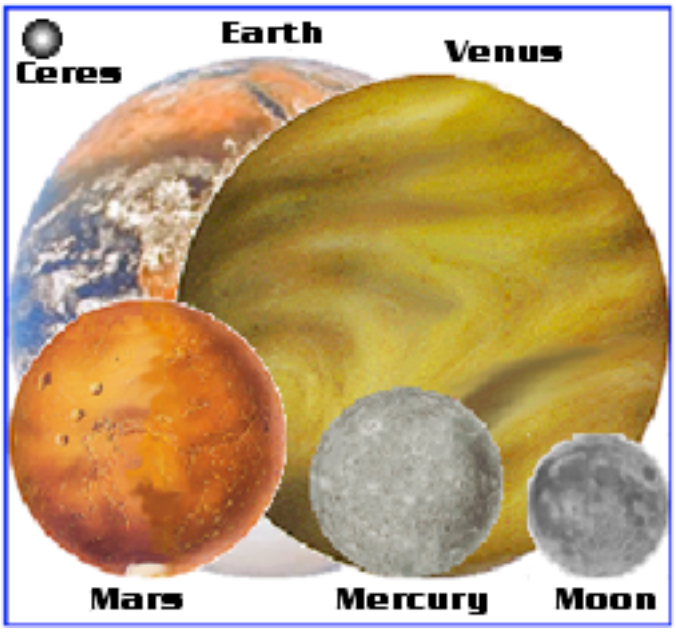
Seasonal factors: Mercury's eccentric orbit means that it alternately it gets much more, and much less light and heat from the Sun than the average figure indicated.

Energy and raw materials are two of the four pillars upon which a planet's economy are supported. The other two are human creativity and time. The careful reader will note that 'location' -- which we hear about often -- is not on the list. In space travel, location is entirely a function of energy. Expend a certain amount f

energy, and you will completely change your location. The implication here is that the cost of generating energy is what will largely determine the cost of transporting from one planet to another.

[Ed. We have another take on this issue. "**Location**" can matter, and far from being a handicap, its all in favor of Mercury's economic potential. It is Mercury's proximity to the Sun that endows it with an energy rich environment, as well as with a very short orbital period. That, in turn, is the reason Mercury has such short intervals between arrival and launch windows with all the other bodies in the solar system. Thus its location will one day make it the Grand Central station/transport hub of the Solar System.

See MMM #78, Sept. '94, p. "Mercury: Gateway Grand Central" republished in MMM Classics #8 p 36, 38-9. www.moonsociety.org/publications/mmm_classics/
Note also that all this solar energy can be used by lasers to decelerate inbound, and accelerate outbound spacecraft.]



Myth 2: "Mercury is too hard to reach"

Which brings up the first of the three great myths about Mercury that have kept it out of the limelight these many years: the myth that Mercury is just too hard to reach. To best understand the issue of flight to Mercury, it is helpful to compare it with a flight to Mars. Suppose, then, we consider two missions, one to each. Both have a crew of four. Both use identical engines, spacecraft and other equipment to the extent the different planets allow.

Both missions leave from Low Earth orbit. For the Mars-bound craft to reach Mars' orbit from Earth's orbit requires a delta-V (change in velocity) of 2.9 km/sec. Not bad. Its delta-V to enter orbit around Mars will be 2.6 km/sec, total 5.5 km/sec. Also not bad.

For the Mercury-bound mission, a delta-V of 7.5 km/sec is needed to reach that planet's orbit, and another 9.6 km/sec to go into orbit around Mercury: 17.1 km/sec total. This is more than three times what is needed for the Mars mission. However, the inference that a manned mission to Mercury will require three times as much propellant as a mission to Mars does not follow.

Using a Hohmann transfer (most economic trajectory) as a baseline for both flight, the one to Mars takes 245 days while we reach Mercury in just 105 days. That translates to a need for only 42% as much food and other consumables needed for the Mercury flight as for the one to Mars. Food would be about 0.75 kilograms per person per day. The 4 person Marsbound crew needs 736 kg, the Mercury crew just 315 kg.

If we assume a 'standard' LOX/LH2 propulsion system, it will take approximately 1.88 kg of additional propellant and spacecraft structure to deliver one kilogram of payload to Mars orbit. The same system would need three times as much propellant/structure mass to get a kilogram of payload to Mercury. However, in terms of actual mass in LEO needed to the respective missions,the Mercury-bound craft would be carrying considerably less payload for a given crew size. In the end, a Mercury-bound ship would require less propellant mass than the delta-V figures above would suggest. An exact figure requires an iterative process for both missions which is really beyond the scope of this study. Our point is that a crew of four could be delivered to Mercury using a craft (with fuel) 25% lighter than a similar one headed for Mars. (Note that propellant mass would be utilized as radiation shielding during solar flares in both cases.)

Off-loading one crew member from the Mercury mission results in a further reduction of mass required. For a 3 person Mercury craft, the weight in (low Earth) orbit is roughly the same as for a 4 person Mars craft. The point here is that mission duration has an equal part in determining mission cost and energy requirements.

A manned flight to Mercury will still require more propellant [per kg of payload] than an equivalent mission to Mars The Mercury mission could use the same technology and same Earth-LEO vehicles - at cost levels only slightly more than those for Mars. The assumption that we could _not_ do a Mercury mission at 'reasonable cost' is just plain wrong.

There is more.

If both spacecraft are solar-powered, the Mercury vehicle will have a power system (presumably a photovoltaic array) weighing much less than thirty percent of its Mars counterpart. A solar array designed to generate 10 kw at Earth's distance from the Sun would be 25 sq m in area; at Mars distance from the Sun 55 sq m; but at Mercury's distance, just 4 sq. m. Power inverter systems would be the same mass in each case, but the net difference in system mass is significant. Each kg of array mass must be boosted from Earth with the requisite mass of propellant as outlined above. Mercury craft array mass is 1/20th the size and mass of that for the Mars craft. This is further to the advantage of a Mercury craft.

Going to Mercury is not necessarily cheaper than going to Mars. Our point is that the delta-V figures do not give an accurate, or even fairly approximate, picture of what a manned flight to Mercury would actually cost. Nor for that matter, do delta-V figures give any indication of whether a transportation system can be operated profitably between a given pair of planets. Of course, all of the foregoing assumes use of chemical propulsion systems. Now it happens that there is an alternative that can make Mercury settlement a very practical proposition - and even reduce the cost of settling Mars in the bargain.

Solar sails hold the prospect of being able to deliver incredibly large payloads to Mercury orbit without expending massive amounts of expensive propellant. Solar sails have numerous advantages over ay chemical system, including nuclear systems. They are relatively low maintenance, completely reusable, totally insensitive to plane-change requirements and the usual launch window constraints, extremely flexible in their payload capacity and pose no risk to crews from either explosions ro radiation exposure. A single Ares launch vehicle can deploy a solar sail 25 square kilometers in area, large enough to deliver a 400 metric tonne payload to Mercury in just 600 days. Three such payloads could be launched every year if need be. There is no chemical technology that can begin to approach this capability for any planet.

In reality, there is no real likelihood of such massive payloads being sent anywhere. The Ares vehicle mentioned is designed to launch something like 150 metric tonnes to LEO. It would require at least three such launches thoroughly equal 400 tonnes. There is an argument that this is not particularly cost efficient.

With solar sails, the issue is more about how fast do we want to get our payload to Mercury. If solar sails have an Achilles' heal, it is that they can take a comparatively excessive amount of time to build up th velocities needed to reach Mercury. Ironically, and this is good news, getting a solar sail back from Mercury is a lot easier and faster, owing to its proximity to the Sun. As a transportation system comprised of several sails, more or less constantly in transit, the average payload could be reduced in size to enable faster transfers. Entire round trips lasting less than a year are easily achievable.

Myth 3: "Mercury is too dangerous to live on"

Radiation on Mercury is considerably more severe than on the Moon or Mars Depending on its orbital position, Mercury can receive anywhere from six to ten times the radiation flux encountered on the Moon. By implication, that means people would build up radiation-induced damage at a proportionally greater rate. This in turn means a crew on Mercury would need much more radiation shielding to reduce dosage levels to a particular point than on the Moon. It also means that the crew could not be exposed to natural radiation levels on Mercury for as long as a lunar crew. But just how long could they go unprotected before accumulating a career limit dose?

There is remarkably little direct information on ionizing radiation effects on Mercury. Most writers on the subject tend to focus on thermal radiation and do not consider that ionizing radiation, by itself, is a hazard because of the damage it causes on the cellular level. Mercury's extreme heat would destroy any unprotected living tissue very rapidly; in mere minutes. Ionizing radiation, on the other hand, destroys by overwhelming the body's ability to repair itself. This takes a bit longer.

Excluding intense solar flares, calculations indicate that a crew could work on Mercury's surface for at least five weeks with only their spacecraft or their space suits for protection. At that point, they would need to b under shielding -- as much as 15 meters of shielding, if it is comprised only of Mercury regolith. Five weeks is more than enough time for an experienced, well - equipped crew to build a small base under adequate shielding. Training such a crew on the Moon prior to Mercury would be logical and beneficial.

To clarify the five-week limit, that would be the length of time it would take the crew to receive a cumulative dosage that would cause a substantial increase in their likelihood of developing life-threatening cancers. It does not mean "five weeks and they are dead." There are some estimates that go as low as only two days (but do not specify the level of protection needed) and others that go up to ten weeks. Uncertainty remains and this is the subject of more study. What is clear is that a crew would have a window of time to establish adequate shielding.

For a crew of four people with just two days working simultaneously, this works out to a total of 192 man-hours or eight man-days - in which to get an initial base built. The more likely scenario is that only half that time would be productive. This still eaves four man-days of actual productive time to deploy the shielding: a worst case scenario that might not pas NASA safety rules.

[Ed. on the question of shielding, I asked the author about the possibility of lavatubes on Mercury. We have only photographed a little more than half of the planet's surface and do not see Moon-lie maria. His reply:

"There are 'sinuous rilles' on Mercury. Mostly they are in the Caloris basin region and they are not likely to have been formed by exactly the same process as lunar rilles. Uncollapsed lava tubes are not yet identified, so far as I know anyway. I have a CD of Mariner 10 images and am poring over them with gret interest and will let you know if i see anything NASA missed. Hey, it could happen. . ."]

As for thermal radiation, the logical approach is not to be out on the surface during times when the Sun is high enough to heat the ground to excessive levels. For current technologies, that still leaves about three weeks after sunrise and three weeks before sunset in which to explore by daylight. Of course, the entire 88-day nightspan is available for surface work, albeit under artificial lighting. Three weeks is more than enough time to conduct very extensive exploration sorties or surface construction work.

Mercury can be reached. We can cope with its environment, if not enjoyably. The rewards for making the effort are great. Abundant energy: a strategic transportation hub allowing access from Earth to Venus and Mars at intervals and with flight times better than direct routing; resources of metals, silicates, and volatiles that ensure self-sufficiency in vital needs such as construction materials, life support elements and even spacecraft propellants. ... The potential is impressive.

Given the advantages of solar sails for low cost transportation, combined with Mercury's many attributes (including the greater accessibility based on shorter synodic periods with other planets) it is even conceivable that Mercury could be developed much more rapidly and at far less total cost than Mars.

That's a subject for a future report ... **<BJ>**

Mercury Probe Updates:

Mercury Messenger is due to fly by Venus on June 5, 2007. and go into orbit around Mercury on March 18, 2011 (in four years.) http://messenger.jhuapl.edu/

BepiColumbo (ESA/Japan) mission in planning www.esa.int/esaSC/120391_index_0_m.html **MMM**

More on Mercury as a Human Frontier

From Dave Dietzler and Peter Kokh

DD: Much of what we know about Mercury was gained by Mariner 10 during three flybys in 1974 and 1975.

A total of 2,300 photos were taken but only 45% of the surface was imaged at an average resolution of 1 km. and less than 1% of the surface at resolutions between 100m and 500m. The other half of Mercury is a mystery.

High resolution radar images of the un-photographed side show three bright features. One may be a large fresh impact crater. Another has a radar signature similar to a shield volcano as big as Mars' Olympus Mons. The third has no known radar counterpart elsewhere.

Mercury's surface is cratered like the Moon and has impact basins similar to those on the Moon. The largest lava plain is the Caloris Basin, 800 miles across. On the opposite side of Mercury there is a feature called the Hilly and Lineated Terrain which probably formed when seismic waves from the Caloris Basin impact converged. Radar studies done by JPL scientists using the Goldstone antenna and the VLA indicate the presence of water ice in northern polar craters and radar images from Arecibo confirmed the results and even discovered a bright patch in the southern polar region.

Because the obliquity of Mercury to its orbit is 0° the planet does not experience seasons (as such) and temperatures in the polar regions should be less than minus 248 F. In permanently shaded craters it could be as cold as minus 290 F. Since the radars could penetrate the ground and the surface of Mercury based on infrared temperature measurements seems to be covered with a porous soil or rock power like the lunar regolith that is a good thermal insulator, the ice could be subsurface. **DD**

PK: That Mercury's axis is not tilted at all, leads some to say that the planet has no seasons: yet the eccentricity of the orbit is such that there are both clearly distinct climactic regions, and a set of seasons in each.

When Mercury is at perihelion, the Caloris basin is always sunward, the antipodal chaotic area in darkness When Mercury is at aphelion, the Caloris antipodal chaotic area is sunward, Caloris in darkness. These areas experience very different climates even if at the same latitude.

At the equator, shade has to be overhead. Away from the equator, shade walls may work, and surface temperatures will be lower (less insolation per sq. meter.) Peri-arctic regions will have the most reasonable temperatures as well as close proximity to ice.

Mercury's day, noon to noon, is 176 Earthdays long. One need travel only 3.75 kph or 2.33 mph to keep up with the advancing sunrise or sunset, at the equator. On Earth, a couple of meters down, the temperature may be temperate (40-60 depending on latitude.) I think Mercury's subsurface temperature will vary strongly with both latitude and longitude along with the local mean insolation per square meter. There not be much relief underground away from the periarctic areas. **PK**

Moon Transmission Yields

By David Semloh <semlohzinc@yahoo.com>

"How to make money from the Moon" asked the May 06 MMM #195. And in Dec 06 NASA published a poll [1] with the same question. Very little extension of the "Arecibo-type dishes [2] was offered in either article.

Possibly the best potential use of the crater dishes is for telemetry and transmission, and implications could be enormous. The previously mentioned Nasa poll at best suggested some lunar based remote terrestrial sensing for mapping and climate studies. But the AM transmission value alone could be in the billions (USD) for 0' lat/0' long crater dishes support of current terrestrial and satellite efforts, if the bottleneck of precision columnation is available at low cost without nonspherical devices.

Agreed, some strong handicaps involving installlation cost exist, the lunar method of time delay, distance, and with being out of contact for half the time with any one part of the Earth. And 6.5' tilt libration preventing a perfect columnation with a parabolic antennae. (Earth spin is not perceived to be a large problem for foci antennae Arecibo-type tracking, but this may be incorrect.)

Nonetheless, lunar platforms are massive and enormously stable for footprints [3], unlike man-made satellites (the latter are unstable and have short lifetime due to station-keeping [4] requirements), which allows long period savings and possible transmission focus that is otherwise impossible. Which suggests a niche market not currently being used, especially with fine tuning resolution. [5] [6] [7] [8]

Pluses and minuses weighed, the idea has great potential. It only suggested that closer examination is in order. Currently involved in receiving more information from some previous Nasa workshops on the subject, I now request input from MMM readers, particularly expert opinion in AM transmission and collection. I admit not being familiar with a great many technical details, but simply see promise in an area others appear to have overlooked. Any positive comments or offered detractors would be appreciated to help settle this proposal.

Relevant and related issues online: [1] http://www.nasa.gov/pdf/163560main_LunarExplorationObjectives.pdf

[2] www.space-frontier.org/Projects/Moon/lunargallery.html

[note Pat Rawlings art above is from this page]

[3] http://en.wikipedia.org/wiki/Footprint_(satellite)

[4] http://en.wikipedia.org/wiki/Station_keeping

[5] http://en.wikipedia.org/wiki/Satellite_radio

[6]http://en.wikipedia.org/wiki/Direct_broadcast_satellite

[7] http://adsabs.harvard.edu/abs/1977ATTM...67..300B

[8] web search Forbes "Broadcast Bullies" **<DS>**

Lunar Zen Gardens Inside & Outside The Blending of Interior and Exterior Spaces

By Peter Kokh

In last month's Mars-theme issue, we discussed how Martian pioneers could blend indoor and outdoor spaces. These pioneers will be working with a different color palette, and eventually, with something more than sand and rock: plants, once Mars-hardy plants begin to take root out in the open under a steadily thickening and warming atmosphere.

On the Moon, we have just regolith (sand analog) and rock to work with. Fortunately, these two elements have been media enough for artists in many cultures from the Stone Age through the present. Stonehenge comes to mind, but that, and many similar pre-Celtic creations are evidently something more than artful arrangements.

When it comes to sand, be it desert or beach sand, people (and children) have been drawing patterns and pictures in them with a stick from time immemorial. http://hebert.kitp.ucsb.edu/sand/tradition.html

But the most refined art form combining sand and rock is arguably the classic, serene Zen Garden, in which an odd number of different shaped stones or rocks are placed in a "sea" of sand, complete with raked "ripples." This is an art form that begs to be translated with lunar elements found everywhere: moondust and boulders.

We can do this out on the surface, but also indoors: below is a design perfect for a lunar home foyer.

Zen Gardens in Lunar Homes

If there is a Zen garden just inside the airlock, there could be another just outside, especially if it is visible, along with persons coming and going, through a periscopic picture window. The garden outside, though constructed of thoroughly natural elements, puts a friendly, welcoming human touch on what otherwise may seem an alien and hostile landscape.

Inside, the Zen Garden will look the same only with very careful preparation. The moondust must first be purged of the troublesome fine powder component, the last thing we want to bring inside our living spaces. Then, using a magnet, one must purge as much of the iron fine component as possible. Why? Because the moondust has never been exposed to humidity before, and will begin to take on a rusty color instead of its characteristic gray tones. The effect would look somewhat Martian. An option would be to use controlled gradual purging of the regolith so that nearest the outside (nearest the airlock) gray tones would predominate, gradually shifting towards rusty shades at the end furthest from the airlock. This could symbolize an assimilation of the lunar environment.

Of course, there is no reason to limit placement of small indoor Zen gardens to the airlock antechamber. They might be even more appreciated in the foyer of a lunar homestead at the entrance to the home from a pressurized settlement street or passageway. Far more visitors will enter lunar homes from other pressurized areas than directly from the out-vac, the airless surface. As such it will be a statement that this is the home of Lunans, people at home on the Moon, welcoming others who have also made that passage.

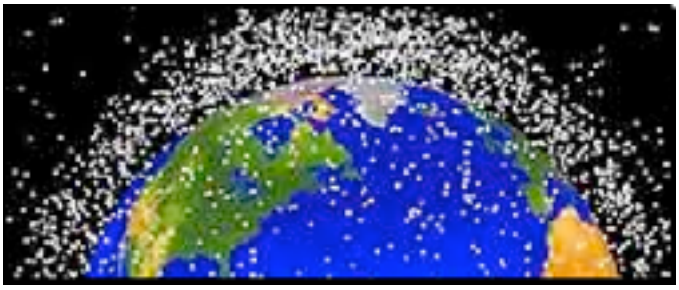
Small **tabletop** Zen Gardens can be put in dens, bedrooms, anywhere people will enjoy having them.

A strange but fitting companion for a small Zen Garden might be a **Bonsai tree** planter, representing the forests left behind on Earth.

Zen Gardens out on the Lunar Surface

There is no reason to restrict Zen Gardens to the airlock entrance areas. On the other hand, as they take some labor in a space suit to create and arrange properly even if all the elements are handy to the location, we are unlikely to see the median strips in lunar versions of our divided highways in the form of a continuous Zen Garden!

We might see them as periodic trail markers, at road junctions, scenic waysides and rest stops. Wherever we create them, they will remind all who pass and enjoy them that we are Lunans, people who have come to live with the Moon in harmony. Zen Gardens, whether indoors or out on the surface, will be a respectful way of saying that we will make the Moon a human world, even as it reshapes us as Lunans into its own people. **<MMM>**



Space Debris Threatens to Close Space Access

While some people have been sounding the alarm for decades with increasing stridency, it is clear that most observors and space enthusiasts have a cavalier attitude towards the growing threat to space transportation to and through low Earth orbit posed by space debris. This one problem could trump all other concerns by confining us to a terrestrial prison for millennia:

www.wired.com/wired/archive/15.05/st_houston.html

Indian Leader's Space Vision Goes far beyond U.S. "VSE"

MMM Special Report

Dr. A. P. J. Abdul Kalam, President of India Speaks to the Symposium on

"The Future of Space Exploration: Solutions to Earthly Problems"

To mark the occasion of the 50th Anniversary of the dawn of Space Age,

Boston University,
Boston, MA,
April 12, 2007.

http://www.presidentofindia.nic.inscripts/eventslatest1.jsp?id=1494s

"Since the dawn of space era in 1957, space science and technology has enhanced man's knowledge of Earth, atmosphere and outer space. It has improved the quality of life of human race. Our space vision to the next fifty years has to consolidate these benefits and expand them further to address crucial issues faced by humanity in energy, environment, water and minerals. Above all, we have to keep upper most in our mind the need for an alternate habitat for the human race in our solar system. The crucial mission for the global space community is to realize a dramatic reduction in the cost of access to space."

Excerpt Highlights

"Today, India has the capability to build any type of satellite launch vehicle to place remote sensing, communication and meteorology satellites in different orbits and space application has become part of our daily life. [...and have demonstrated space capsule recovery.]

"India is now working on its second space vision which will include space missions to the Moon and Mars *founded on space industrialization.*

"Space Research has been a Technology Generator, consistently aiming at t*he impossible* and *the incredible.* It is almost a "Green Technology. ... The world population is projected to be 9+ billion by 2050. Critical issues arising from this growth are shortage of energy, shortage of water and increasing damage to the natural environment and ecology. ... What better vision can there be for the future of space exploration, than a global mission for perennial supply of renewable energy from space?

Water for future generations

"There is a four-fold method towards providing safe and fresh drinking water for large population. The first is to re-distribute water supply; the second is to save and reduce demand for water; the third is to recycle used water supplies and the fourth is to find new sources of fresh water. Desalination is an energy intensive process. Hence, the use of renewable energy through space solar satellites can bring down the cost of fresh water substantially. Space based solar power stations have six to fifteen times greater capital utilization than equivalent sized ground solar stations. Linking Space solar power to reverse osmosis technology for large-scale drinking water supplies could be yet another major contribution of Space.

Potentially Dangerous Asteroids

"Space community has to keep monitoring the dynamics of all potentially dangerous asteroids. Asteroid 1950DA's rendezvous with Earth is predicted to be on Mar 16, 2880. The impact probability calculations initially indicated a serious condition of 1 in 300 which has to be continuously monitored. In such a crucial condition, we should aim to deflect or destroy this asteroid with the technology available.

Space Missions (2050)

"Geosynchronous Equatorial Orbit (GEO) is a well utilized resource. The spacecraft orbiting in GEO are very high value resources. However, the life of these spacecraft are determined by component failure, capacity of fuel, internal energy systems and space environment.

"While new design practices and technologies are constantly increasing the life of satellite, there is a requirement for extending the life of satellite through in-orbit maintenance such as diagnosis, replacement, recharging, powering, refueling or de-boosting after use. This calls for creation of Space Satellite Service Stations for all the spacecraft in the GEO as a permanent international facility. Future satellites and payloads have also to be designed with self healing capability and midlife maintenance.

Space Industrial Revolution

"Mankind's 21st. Century thrust into space ... means is the creation of architectural and revolutionary changes leading to new space markets, systems and technologies on a planetary scale. Such a Space Industrial Revolution will be triggered by the following missions that can address all segments of the global space community. What are the possible drivers for such a Space Industrial Revolution?

"The first major factor will be man's quest for perennial sources of clean energy such as solar and other renewable energies and thermonuclear

fusion. Helium 3 from Moon is seen as a valuable fuel for thermonuclear reactors.

"The Moon's sky is clear to waves of all frequencies. With interplanetary communication systems located on the farside, the Moon would also shield these communication stations from the continuous radio emissions from the Earth. Hence *the Moon has potential to become a "Telecommunications Hub" for interplanetary communications also.*

"The Moon also has other advantages as a source of construction materials for near Earth orbit. Its weak surface gravity is only one-sixth as strong as Earth's. As a result, in combination with its small diameter, it takes less than five percent as much energy to boost materials from the lunar surface into orbit compared with the launch energy needed from Earth's surface into orbit. *Electromagnetic mass drivers powered by solar energy could provide low-cost transportation of lunar materials to space construction sites.*

Habitat on MARS

"As my friend Prof UR Rao, former Chairman of ISRO says, space scientists are habituated to protecting systems against single point failures; so, in the longer term, creation of extra terrestrial habitat on MARS should be studied as fail safe mechanism for our problems on Earth. How would we create livable conditions on Mars?

Moon-Based Solar Power Stations

"The non-availability of low cost, fully reusable space transportation has denied mankind the benefit of space solar power stations in geo-stationary and other orbits.

"The Moon is the ideal environment for largearea solar converters. The solar flux to the lunar surface is predicable and dependable. There is no air or water to degrade large-area thin film devices. The Moon is extremely quiet mechanically. It is devoid of weather, significant seismic activity, and biological processes that degrade terrestrial equipment. Solar collectors can be made that are unaffected by decades of exposure to solar cosmic rays and the solar wind. Sensitive circuitry and wiring can be buried under a few- to tens- of centimeters of lunar soil and completely protected against solar radiation, temperature extremes, and micrometeorites. Studies have also shown that it is technically and economically feasible to provide about 100,000 GWe of solar electric energy from facilities on the Moon.

One Major Problem

"How are we going to make the cost of access to space affordable?. The question hinges on creating space markets and developing cutting edge technologies to make low cost of access to space a reality. The future of the space industrial revolution created by a space exploration initiative would hinge greatly on new means of safe, affordable access to near earth space, as the platform for deep space exploration.

Cost of access to Space

"The present level of markets for communication, are getting saturated. ... The current cost of access to space for information missions such as telecommunication, remote sensing and navigation varies from US $ 10000 to US $ 20000 per kg in low earth orbit.

Hence "the future of space exploration requires that space industry moves out of the present era of information collection missions, into an era of mass missions. There is a need to reduce the cost of access by two to three orders of magnitude. It is only by such reduction in cost of access to space that mankind can hope to harvest the benefits of space exploration by 2050.

Affordable, Low Cost Space Transportation

"The payload fraction of current generation expendable launch vehicles in the world does not exceed 1 or 2% of the launch weight. Such gigantic rocket based space transportation systems, with marginal payload fractions, are wholly uneconomical for carrying out mass missions and to carry freight and men to and from the Moon.

"**Studies in India** have shown that **the greatest economy through the highest payload fractions** are obtained when fully reusable space transportation systems are **designed which carry no oxidizer at launch, but gather liquid oxygen while the spacecraft ascends directly from earth to orbit in a single stage.** These studies in India suggest that a "aerobic" space transportation vehicle can indeed have a 15% payload fraction for a launch weight of 270 tonnes. **This type of space plane has the potential to increase the payload fraction to 30% for higher take off weight.** For such heavy lift space planes, with 10 times the payload fraction and 100 times reuse, the cost of payload in orbit can be reduced dramatically by several orders of magnitude lower than the cost of access to space with expandable launch vehicles.

"The real value of space exploration for human advancement will occur only when mankind builds fully reusable space transportation systems with very high payload efficiencies. This will become available when the technology of oxygen liquefaction in high-speed flight in earth's atmosphere is mastered.

Maintaining Peace in Space

"There is a need for an International Space Force made up of all nations wishing to participate and contribute to protect world space assets in a manner which will enable peaceful exploitation of space on a global cooperative basis. **Challenges before the Space Research Community**

"The scientists of today must come up with a steady fountain of ideas that would attract the students. This is a great challenge. I would be happy if the great minds gathered here, articulate to the young, the space vision for the next fifty years and challenges presented and discussed in the Symposium. Space does not have geographic borders and why should those who pursue space research have any borders?

Space Missions 2050

"I would like to suggest the following space missions for the consideration by the space community assembled here to be fully accomplished before the year 2050.

1. Evolving **a Global Strategic Plan** for space industrialization so as to create large scale markets and advanced space systems and technologies, **for clean energy, drinking water, tele-education, tele-medicine, communications, resource management and science; and for undertaking planetary exploration mission.**

2. Implementing **a Global Partnership Mission** in advanced space transportation, charged with the goal of **reducing the cost of access to space by two orders of magnitude to US $ 200 per kg.** using identified core competencies, responsibilities and equitable funding by partners, encouraging innovation and new concepts through two parallel international teams
3. Developing and deploying **in-orbit Space Satellite Service Stations** for enhancing the life of spacecraft in GEO as a permanent international facility.

"Interplanetary exploration is a necessity. Living people of the planet Earth have to pave the way for alternate abode for human beings." *– Abdul Kaman*

[**Editorial Comment:** If you read carefully, you will have noticed several points that blow the Bush-Griffin Vision literally out of the water.

√ Kalam presents a well-thought out plan for achieving drastic cuts in space transportation. In the VSE, all that is foreseen is deployment of a token, "visitable" Moon station which could be done with the minimally improved transportation hardware on NASA's drawing boards. But Kalam sees wholesale industrialization of the Moon to provide clean energy to Earth and reverse environmental degradation.

This is not going to happen without very large reductions in space transportation costs.

Further evidence that we need NASA out of the Space Transportation business.

√ He sees the need to open up the Martian Frontier so that all of humanity's "eggs are not in one basket." –

Kudos! We need to adopt this Vision! -- PK]

Mercury Frontier Speculations for the fun of it!

By Peter Kokh

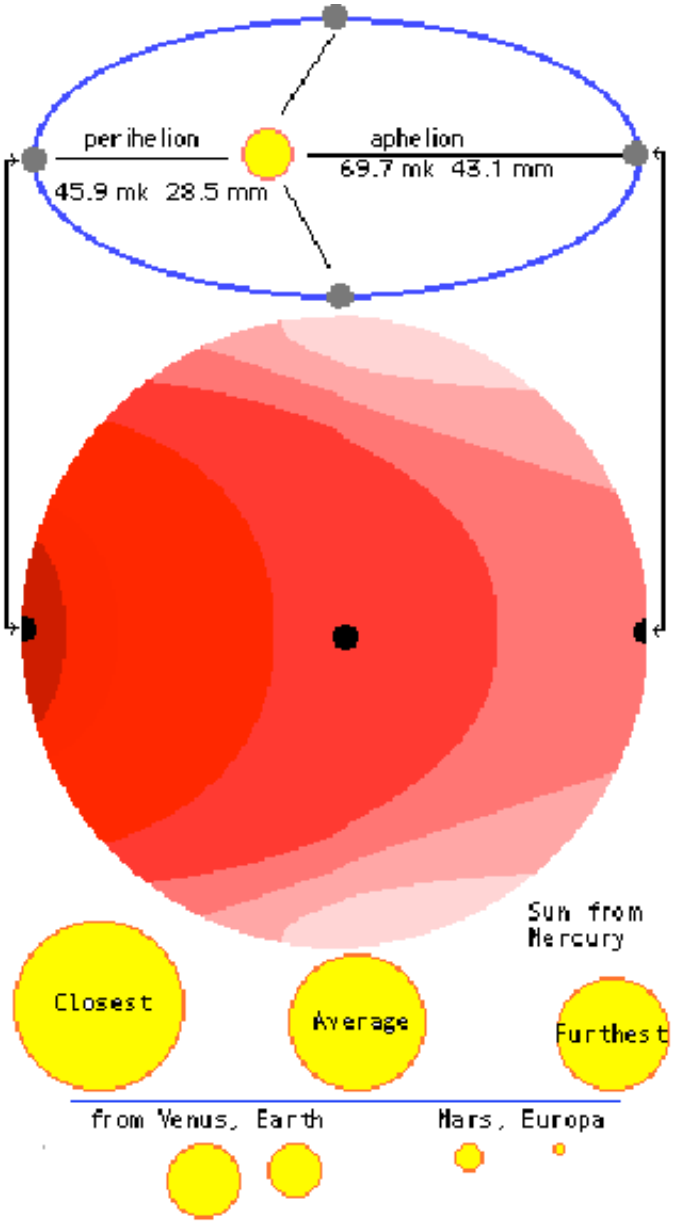
Climate Zones – dayspan temperature swings

Notice the cooler area surrounding the poles hugs the pole more closely on the side of Mercury that faces the Sun at perihelion, than the aphelion facing side. The idea of creating this climate zone graphic is to show in which areas it would be relatively easier or relatively harder to set up a manned presence.

Shade, Thermal Shielding, and Burrowing Down

Shade is one thing. Shade protects you from further heating from the Sun above. It does not protect you from the heat already accumulated in the ground below. To find lower temperatures, we'll have to do what we do on Earth, dig down. On Earth, and we think on the Moon, the temperature a couple of yards or meters down stays fairly even year around. That temperature level is higher the closer you are to the equator, and colder, the closer you are to the pole. Tap water is wonderfully cold in the northern states and Canada, but almost luke warm in the southern states.

As Mercury is much closer to the Sun, it receives an average of nearly seven times the solar influx per square meter as does Earth or the Moon. The subsurface ground temperature will vary with the climate zones we sketched at right. But the subsurface temperatures are likely to be quite high by our standards.



Above you will see how much larger the Sun looks from Mercury at its closest approach to the Sun in comparison to its furthest recession. From Earth, the Sun looks much smaller, yet quite a bit larger than it does from Mars. By the time you get out to the great moons of Jupiter, The Sun still looks round, but now very much smaller. From Neptune and Pluto, it looks more like Venus looks in our sky, only, much, much brighter.

Obviously the light colored (graphic above) polar zone would be the coolest area for a settlement. But, I, for one, am not confident that the subsurface tempera-

tures will be low enough for even there. We need ground probes that can drill 10-20 meters (31-62 feet) down to be sure of that.

According to Bryce Johnson's research (see last month's article on Mercury), we'll have to burrow that far down (or tuck ourselves under a blanket of regolith that thick) to protect ourselves from Mercury's much greater solar flare flux than we are used to in Earth-Moon space. As to Cosmic Rays, their intensity will be the same everywhere we go within, and without, our solar system.

Obviously, the discovery of intact lavatubes will be of even greater significance for shelter than for the Moon or Mars. While the one side of Mercury that we have mapped on a quick swingby, shows no abundance of maria like features, there do appear to be some lava flows, and wherever there are lava sheets, there are likely to be lavatubes. If we find areas in which there have been more than one episode of lava flooding, there may be lavatubes intact in each layer. And the lower we go down the more protection we will find.

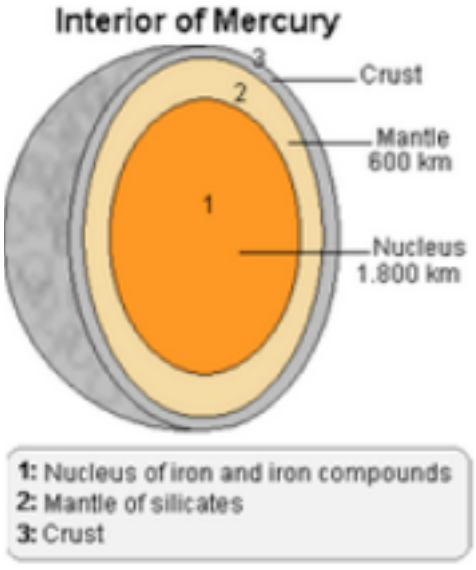
But there is a possible Catch-22. Here on Earth, in deep mine shafts, we find that the lower we go the hotter it gets and that the cool temperatures between 6 and a thousand feet down or so, are all the buffer zone we get. Below that zone, we start to feel the heat of the Earth below. That heat comes from billions of years of radioactive decay. Will we find a similar situation on Mercury. *Maybe, maybe not.* Read on.

Mercury is not evenly hot all over

Mercury's rotation is sun-locked -- sort of. It does not always keep the same face to the Sun at all times, but in its very eccentric orbit, it revolves at a pace that allows it to present the same face towards the Sun when Mercury is closest to the Sun (Perihelion) and the opposite face is always turned towards the Sun when the planet is furthest from away in its orbit (aphelion.) The diagram sketches both Mercury's orbit and the resulting climate zones, hottest to coolest. Those of you who get MMM as Black & White hardcopy only, will not be able to see the climate zones. So we put this diagram online at: www.lunar-reclamation.org/images/mercury_zones.gif

Mercury's Internal Heat

Compared to Earth, the first planet has a very large iron core, and an overall density similar to ours. This core may not be molten or have a molten mantle above it. But it will be hot, both from the residual heat of its contraction and formation and from radioactivity



The $64 question is what is the temperature of the subsurface layer in which both solar heat and internal heat bottom out? Will there be a sweet cool layer that is thermally friendly?

It matters not how well endowed the planet is with resources that could support an industrial civilization if there is nowhere on the planet's surface or not to far below it, that we will find cool enough? What is cool enough? Human activity, especially in our current state of energy use, produces surplus heat. We will need a heat sink. We'd like to find a subsurface area that is well below freezing. Therein, just the heat of daily living will keep us as warm as we want to be.

We can do our best to come up with an educated guess, but there is nothing so reassuring as actual readings, meaning, we have to go there, and find out, if not in person, then via our robots.

The Polar areas

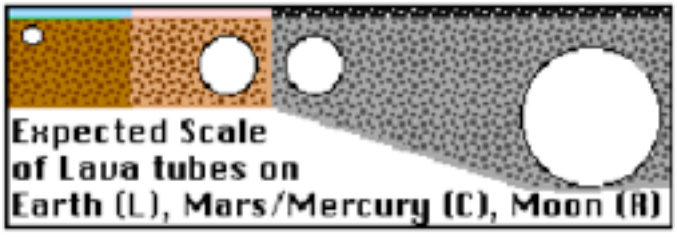
If we confirm the existence of frozen water-rich volatiles in permashade craters near both the Moon's poles, we are likelier to find plenty in similar coldtraps on Mercury. Mercury, even though it is closer to the Sun, and therefore both warmer, and possibly a less frequent target of impacting comets, has an edge in that there is only a small fraction of a degree, ~ one arc minute, of tilt in Mercury's axis to the plane of its orbit. The Moon's tilt is about 1..5° - thus on the Moon, there are crater areas that are shaded most, but not all of the time.

The Goldstone 70-meter antenna transmitting and 26 antennas of the Very Large Array receiving, has provided evidence for the presence of polar ice in craters around the north pole of Mercury, in 1991, seven years before Lunar Prospector found evidence of polar ice deposits on the Moon. Some, confusing the usually poor odds of good luck, with nature's laws want to find any other explanation. But hydrogen is the most common element in the Universe, with oxygen third. No molecule is more likely to be abundant than water, H2O. If Ockham's Razor is worth considering, water is easily the most elegant, the most simple, and the most natural explanation.

Evidently, Mercury's polar subsurface temperatures are cold enough, any internal planetary heat notwithstanding. That is good news! It means that if we dig down elsewhere, it will likely be cold enough there also.

Mercury's Lavatubes

On Earth, we find lavatubes wherever runny, notso- viscous lava has flowed. We find them in shield volcanoes, with gentle profiles unlike Mt. Fuji or other classical cone volcanoes. Thus the Island of Hawaii, which in its entirety consists of that portion of the flanks of the twin volcanoes, Mauna Loa and Mauna Kea, above sea level, is honeycombed with lava tubes. Now we find shield volcanoes of gargantuan proportions on Mars, but none on the Moon that we have yet identified as such.



However, we find them on Earth and on the Moon in lava sheet flows. The first evidence was the many sinuous or winding rille valleys, which are now universally

believed to be collapsed lavatubes of vast proportions. That lunar tubes are so much larger in scale than terrestrial ones, both in length and in cross section, suggests that in this case, size is in an inverse relationship with the host planet's gravity. The gravity on Mercury and Mars is two plus something times greater than that on the Moon and about three eighths that of Earth. So we might expect lavatubes on Mercury to be comparable to those on Mars, and somewhere in between in size, but still eminently usably as ready made shelter form the hazards of cosmic weather and thermal extremes.

Bryce Johnson reports several sinuous rilles in mare-like areas on Mercury. The total volume of uncollapsed lavatubes on Mercury is likely to be much smaller than that on Mars were such flows were immense, or on the Moon, both because lunar tubes are likely to much larger in scale and because on the one hemisphere of Mercury that we have photographed, the extent of lava sheet flooding has been comparatively minor.

Any intact lavatubes on Mercury, could support settlements, industrial parks, warehousing, you name it. Those nearest the poles in the more thermally less extreme climate zones would have the edge. Unfortunately, the areas where conditions were right for lava sheet floods and the formation of lavatubes may not conveniently coincide with those sections on Mercury that have relatively cooler climates.

Around and around – Keeping up with the terminator

That Mercury's dayspan-nightspan cycle is so long, 176 days or 6 months long, provides an advantage. On Earth, the terminator advances at over a thousand miles an hour at the equator and about 750 miles an hour at mid latitudes (mid 40's, north or south). On Mercury, at the equator, the sunrise and sunset terminators advance some 87 km = 54 mi per day, or just 3.6 kph = 2.2 mph. One can almost walk that fast, though probably not in a space suit. As you go further away from the equator towards either pole, that slow walk becomes a crawl.

Put it another way, the sun marches across the sky at just 2° a day, compared to 360° here on Earth.

The area just behind the sunrise terminator will likely be much more pleasant than the area just ahead of the sunset terminator. Ten days after sunrise, the Sun will be only 10° above the horizon at best, less, away from the equator. One could linger in an area for a week or more before moving on.

Imagine, if you will, a circumpolar railroad, that hugs the pole on the side of the planet facing the sun at perihelion, and dropping to lower latitudes on the side facing the Sun at aphelion, say along the interface between the coolest two zones in the graphic, page 30.

Now imagine six settlements along the track. One could move to the next settlement every 29.3 days, or if there were just five settlements, every 5 weeks.

The permanent part of each settlement would be living space, with the highly functional spaces on railway cars, along with the expensive mining and processing equipment. It would be a different way of life, but one more settled than that of terrestrial nomads. Consider how many persons now have two homes, one for winter months, another for summer months.

Each trackside settlement would have to be dud in, of course, just to be safe from radiation hazards. If actual time spent traveling from one location to the next was relatively trivial, say a day or two at most, the railroad track could be simply covered with a shielded shed all along its route.

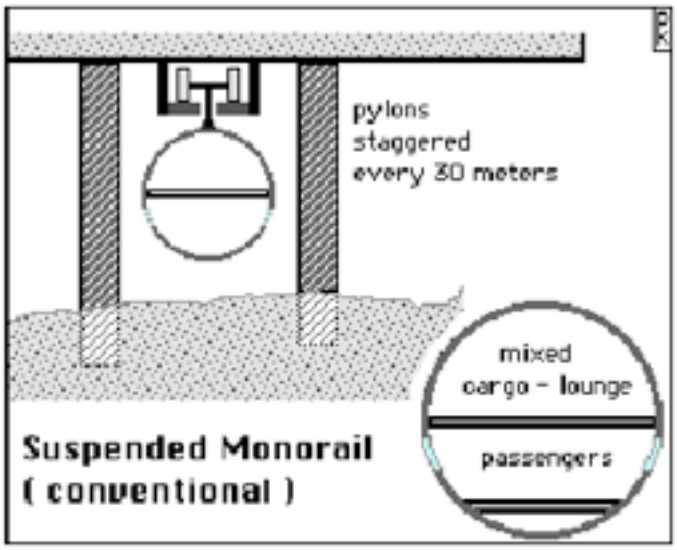
Sound like too much of an adjustment? Consider the adjustment northern peoples have made since leaving Africa. Humans are amazingly adaptable, and quickly adjust to new surroundings and conditions, learning to be at home there, learning to love their new life style. In time, humans will spread wherever they can find away to support themselves long term.

On the Moon, Mars, and Mercury, there is no real need to stick with narrow gauge tracks. Right of way is not a problem. We just need to make wider bridges, cuts, and tunnels. An average rail car could be two floors and double the width we are accustomed to having.

On Mercury, solar power at nearly seven times the intensity at which sunlight is available on Earth, could power rail systems. Overhead monorails would fit in nicely with overhead shielded shed structures.

Of course, if we can find sufficiently abundant materials with which to make a circumpolar superconducting maglev line, that would work too.

All we have to do is survey the route, and if the terrain does not lend itself, make the necessary alterations. Now a monorail system under a shield shed all along the way, would simply adjust pylon length rather than smooth out the host right-of-way terrain.



North circumpolar or south? The overall ease of the terain and the comparative wealth of resources along each route would be factors to consider. Just were the north and south magnetic poles are located might also be something to consider.

Mercury Trivia

- **The surface area of Mercury** is about one seventh that of Earth: ~28,000,000 sq. mi, ~73,000,000 sq km, or put in more familiar terms, ***about as large as North and South America and Africa together***, and twice as extensive as the surface area of the Moon.
- **No intra-Mercurial planet** or asteroid has ever been found, false reports of one hastily christened Vulcan, notwithstanding.

- **Mercury's orbital eccentricity and inclination** of its orbit to the main plane of the Solar System (which should be that of Jupiter's orbit, not Earth's) are both much greater than for the other inner planets. Is this the relic of some major impact earlier in its history? The Caloris Basin, is the largest impact site we are aware of on Mercury, but we have only photographed one hemisphere.

Mercury Messenger Trivia

- This is a Discovery class mission
- To become the first spacecraft to orbit Mercury, Mesenger must follow a path through the inner solar system, including one flyby of Earth, two flybys of Venus, and three flybys of Mercury
- Due to arrive in orbit about Mercury four years from now, March 18, 2011, Messenger is the first craft to orbit around the quicksilver planet
- These seven instrumetns are on boad: Mercury Dual
- Imaging System (MDIS), Gamma-Ray and Neutron
- Spectrometer (GRNS), X-Ray Spectrometer (XRS),
- Magnetometer (MAG), Mercury Laser Altimeter (MLA)
- Mercury Atmospheric and Surface Composition
- Spectrometer (MASCS), Energetic Particle and Plasma
- Spectrometer (EPPS)
- Mercury Messenger is designed to answer six broad scientific questions:
- Why is Mercury so dense?
- What is Mercury's geologic history?
- What s the structure and state of Mercury's core?
- What is the nature of Mercury's magnetic field?
- What unusual materials lie at Mercury's poles?u
- What volatiles are important at Mercury?

official site: http://messenger.jhuapl.edu/

Brainstorming for fun and profit?

Well, I don't know about profit, but the fun of this exercise is in looking for ways to extend a human presence on Mercury beyond the poles.

We learned that not all of Mercury is uniformly hot, that there may be natural shelters in convenient places, in the form of lava tubes.

We realized that the slow march of the Sun across the Mercurial sky opens up plausible semi-nomadic lifestyle options.

By the time we get to go, we'll probably have found many more choices than these.

The "Manifesto" of "Moon Miners'" is the brash assertion that we can make ourselves at home on other, seemingly alien worlds, and end up thriving.

<MMM>

"Only those who risk going too Far can possibly Find out how Far one can go."

T. S. Eliot

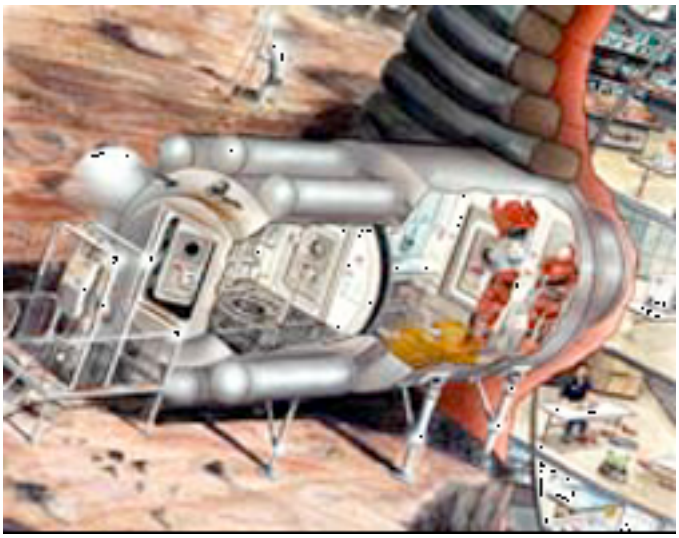
Who's Afraid of "Big Bad Moondust?"

By Peter Kokh

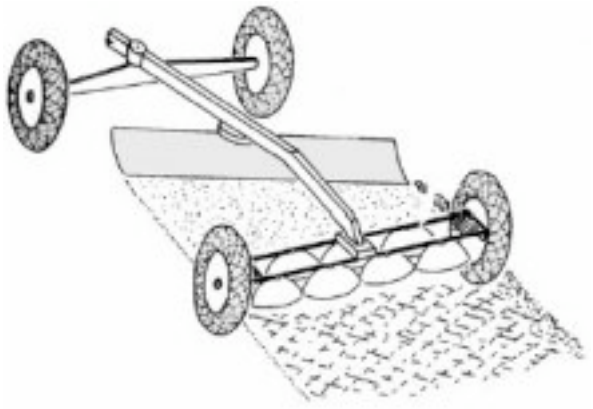
I've seen a good number of articles in the past year or so, to the effect that "the moondust problem" is so intractable that perhaps we should rethink our plans to return to the Moon. So what's new? There have always been people like that looking for excuses why others should not do what they are not interested in. And guess what, those of us who have wanted to something, supposedly too against the grain, have always, always found a way. So much for the Power Of Negative Thinking?

Of course the moondust has some troublesome qualities! But all the evidence from tens of millennia of human history shouts, "so what?" Yes, the dust tends to get in everywhere, potentially fouling engines, gears, bearings, and even human lungs. Potentially! But that will be so only if we don't rise to the occasion with customary ingenuity and "Wasourcefulness." And, of course, that is just what has been happening.

NASA, of course, has thought much about this problem as well, and decades ago (yes, it's been that long since December, 1972) proposed a car-wash type spacesuit cleaning antechamber to the conventional airlock. If we had to have one of these ultra-expensive modules for every airlock, that certainly would have put a serious damper on our future on the Moon. We need toi look for a suite of simpler, less expensive, ore elegant solutions!



The Lunar Moondust "Lawn Mower"
www.moondaily.com/reports/Lunar_Lawn_Mower.html



Larry Taylor, Distinguished Professor of Planetary Sciences at the University of Tennessee has an idea: Don't try to get rid of troublesome moondust -- melt it into something useful! The achilles heel of moondust as an opponent challenging our hopes to make a second home on the Moon is that a significant fraction of its powdery fines contain iron: making moondust amenable to control by magnetism. Taylor once put a small pile of lunar soil brought back by the Apollo astronauts into a microwave oven. And he found that it melted "lickety-split," he said, within 30 seconds at only 250 watts.

Taylor foresees application of this moondust taming technology for sintered rocket landing pads, roads, bricks for habitats, radiation shielding, even Arecibo-like mirrors in small craters -- useful moon-dust-fused products and dust abatement, all at once.

Moral of this story

A lesson I learned from my mother in my early teens is that if you see something as a disadvantage and as an obstacle or even a show-stopper, evidently you are looking at it from the wrong perspective! The key is not to ignore that negative aspect but to embrace it and turn it into the cornerstone of your plan. Reverse the tables!

There are many space advocates who are unfortunately easily discouraged by reports of obstacles: radiation from solar flares and cosmic rays and the mischievous behavior of fine moondust particles being two of the most frequently cited such "downers." We must tackle these head on, and, rather than ignoring or dismissing these facts and conditions, embrace them and keep looking at them from new angles until we see them as the anchors of a plan to succeed in our efforts to make ourselves truly at home on the Moon and in space.

Attitude is everything, and temperament can either be the real problem, or the real solution.

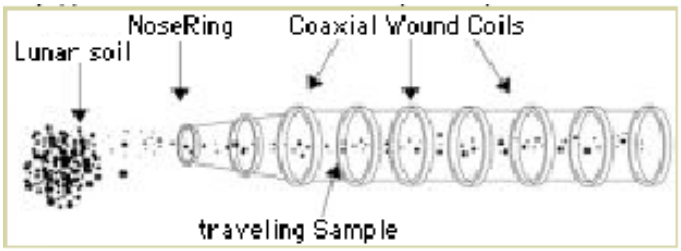
Relevant Online Articles

Magnets Might Foil Moondust - Apr 07, 2006

www.moondaily.com/reports/Magnets_Might_Foil_Moondust.html

Magnetic 'elephant trunk' sucks up lunar soil

http://www.newscientisttech.com/article/dn11406



The humor Dept: If you can't beat 'em, join 'em

Texans know what to do with a dusty car window!

By Paul Swift < pswift@shaw.ca > Calgary, AB Canada

Rick Tumolinson's oft quoted remark that "NASA should open the door to space, not be the door to space," puts me in mind of some of the steps achieved in early Aviation development to which there seems to be a parallel here.

Admittedly this is just a rant on the transportation segment of a much more comprehensive initiative to settle space, but it's not hard to extend the train of thought to several of the settlement and development areas that bear addressing.

When the Wright Brothers flew on Dec. 17, 1903 at Kittyhawk, they did not instantly achieve worldwide fame, nor did they establish as of that date even in aeronautical circles a widespread acceptance of the possibility of manned flight. It wasn't until they visited France five years later and demonstrated on 08/08/08 before an enormously skeptical but excited crowd of aviation experts and enthusiasts that flight was possible and immediate and attainable by two chaps working in their bicycle shop that the ignition took place.

Within a period of about two years, some one hundred and fifty different designs in dozens of countries were airborne, because some upstarts from nowhere had basically spit in their face. The rest is history.

In 1935, twenty-two years to the day from the Wright's first flight, the DC-3 became the workhorse aircraft of the world. It opened up vast stretches of Alaska, Africa, India and Burma, The Philippines and Indonesia, South America, and got the USA into large scale airline operations. Donald Douglas' Cargo or passenger plane was an 'opening door' to the world, and we did whatever we did with it. And we still do. One thousand (of the thousands made) are still in use over seventy years following their construction. Douglas didn't say how to design the airports or terminals, what cargo to carry, how to paint them, or who could operate them. He just built them, established spares and maintenance programs, and had his manufacturing facilities churn out a rather ungainly, awkward, lumbering beast that worked. (Actually I love the airplane; I think it's a thing of beauty and would dearly love to own one.) [1]

Incidentally, there is no more economical way of transporting twenty eight people and their baggage a hundred and fifty miles per hour over inaccessible terrain than the DC-3, and this is being written in May, 2007. The Boeing 707 did the same for fast international travel, and the 1947 Piper Cub did the same for everyman and

his wife. These are standards, milestones, and icons for us to refer to when we think of space systems.

In 'Blood Diamond' recently they used a Russian MI-8 helicopter (the white one) to move people and supplies around the impossibly hilly terrain of Sierra Leone (Madagascar

in the movie). It is bulky, fuel inefficient, and ungainly, but it works like hell! My pilot friend Don who flies a Bell 212 with an empty weight of about 5,500 lbs and gross of 11,000 says the MI-8 can only lift about 5-6,000 pounds, just like the 212, but weighs 16,000 pounds empty. Not too efficient. But in a world in which no helicopter at all, or a slightly ungainly, inefficient monstrous sixteen thousand pound beast lands to transport you and your family to a safer region, I think it is safe to say that 'optimum' is not the keyword; the best phrase we can find is 'functionally adequate'.

We need a Space Piper Cub, a Space DC-3, and a Space MI-8. Note that none of these, like their name-sakes, are expendable or discardable, they would not be optimally efficient, they would not carry the most the fastest or the furthest but they would work. They would work on the Moon and they would work on Mars. They would work in the asteroids, and in space itself.

In 1946, the government of Newfoundland on the east coast had a group of nine ships built called coastal freighters. Their job was to transport cargo (mainly coal and fish) to and from all the little outposts around the island. They were a far cry from the state of the art in boats at the time, being built of wood and using massively overbuilt clunky old diesel engines. But they worked. With a top speed of about eight knots, they could take all the Atlantic could throw at them, and survive.

Sometimes the craft for the job has to match the job requirements in such a way as to preserve the structure as carefully as the crew. The ships were only about 500 gross tons and 127 feet long, but for years were the mainstay of support of those little coastal villages. I was fortunate enough to own one of them, the Avalon Voyager II, a few years back.

We are talking here about a family of transportation devices. For getting around the Moon or Mars or the asteroids, the same solution may be unlikely, but the solutions should have some common characteristics. All need a crew cab, a life support system, a power system, a navigation system, a fly-by-wire system, a control system, a running gear system, a communication system. Why should effort be expended on custom solutions for each of these requirements when they can all be the same, admittedly tailored for the specific implementation?

Today we can see some small efforts in this direction by Airbus, or EADS, in the cockpit design of several of the A3xx series of aircraft in which the layout and functionality of cockpit controls is almost identical from model to model.

The point is this: a big problem can be divvied up into smaller ones. And small problems are just challenges.

Case in point: getting into orbit. (One of the trivial ones :)

Why have six motors of a million pounds thrust each to lift up a four million pound vehicle to the twenty percent point of orbital velocity, then throw them all away as the next stage cuts in? I'm not sure what a million pound thrust motor (rocket engine) would tally these days, but I'll bet I'd have to pay a hell of a GST (Goods and Services Tax) at the U.S./Canada border to get the suckers through. In any case, their cost becomes the base 'nut to crack' to generate revenue from, or simply pay for the launch. At ten million dollars each, there's sixty million of revenue just to cover their direct costs. The Shuttle of course is just as bad. 35 Million or so for the External Tank, and about the same to refurbish the SRB's. *Incomprehensibly stupid.*

Go for the launch system that doesn't use up anything except fuel. Reuse it every day, several times a day. Like the DC-3. Yes, it could be more efficient, but let's make it cost effective for the one who hires the launch service. There's the difference between #3,000-$4,000 a pound to LEO and $15-#20 a pound.

In the early 90's, a friend of Mine, Donny, got a job with Ethiopian Airways flying a cargo Boeing 707. He was the co-pilot. They had the pilot, a grizzly old veteran of African air operations, Donny, and a mechanic back at Addis Ababa. About once a week the mechanic changed the oil. Since they had four of everything, they just kept flying until they only had three, then had the offending piece replaced. Admittedly, this maintenance philosophy wouldn't quite cut it in North American airline operations, but Africa is Africa. Bottom line is: they operated the hell out of that plane to make money and move goods.

The name of the game is Operations, not experimental launches. You do experimental launches with 3,000 personnel on the ground to prepare for the next launch; when you operate, you use a dozen, or in Donny's case, three. Take up another load; land, refuel, reload, and repeat until the maintenance manual enforces an hour shutdown for scheduled inspections and replacements. Then continue. That's how to do it, and so what, like the MI-8, if it isn't quite so efficient in its payload to weight ratio? **It works. It's cheap. and it gets the job done.** And like the coastal freighters that stayed afloat in 1949's worst storm at sea in a century, where over fifty ships were sunk, the nine coastal freighters survived to work again the next day.

Robert Zubrin's Pioneer may have gone back to sleep 'til a better design dcomes along, and to some extent Andrews' Two Stage To Orbit, runway based, Alchemist system could step up to the plate. So industry and entrepreneurs are the ones to watch for the new ideas about getting into space. **<PS>**

Ed. I had my first plane ride in a DC3 also, in 1948. PK

MODULAR BIOSPHERICS

VI. Food Production with Diversity: vegetables, dwarf fruit trees, herbs & spices

By Peter Kokh

Most of the "Experimental Lunar Agriculture" projects I am aware of, were attempts to show that we could grow various staples, notably wheat and potatoes, under lunar greenhouse conditions. While it is essential that personnel on the Moon receive adequate nourishment, the "human system" requires more than just nourishment. If humans are going to be productive in frontier situations, they must be reasonably content.

Now a lot of factors come in here, but one thing is not debatable. Tasty and varied menus are indispensable to keep personnel productively content.

From that point of view, we need a variety of vegetables and carbohydrate sources. Those that can be prepared in a number of different ways rise to the top in priority, potatoes, for example, but also several others.

Nor do most people long tolerate bland food, unless you happen to be British :-) Vegetables and Salad Stuffs are not enough. Most of us would dearly miss occasional or regular fruits. Now the problem with fruit is that most fruit plants take longer to mature than vegetable plants do, significantly longer. Short bushy fruits like blueberries and strawberries might be the place to start. Apples, for example, would not be available very soon. Cultivating dwarf fruit trees makes sense, not only for quicker maturation, but to fit limited cubic greenhouse space.

Herbs & Spices must not be neglected. These additions can be added by each person to prepared and pretested food items, to suite their taste. Some cannot tolerate spicy foods at all. Myself, I can consume XXXX buffalo hot wings with no problem.

Cultivating plants with medicinal and pharmaceutical value would be a smart choice, if only to cut down on the import of over-the-counter remedies.

Beyond the Greenhouse

The communal greenhouses will of necessity concentrate on the key staples and principal vegetables. But if our outpost morphs into a settlement by modular additions, and if we follow the principles of "Modular Biospherics," we will have many opportunities to grow supplemental crop varieties.

If each module has a Wolverton type toilet waste graywater system, some of the plants involved could be herb, spice, and pharmacopeia varieties. Living walls in connector passageways give ample opportunity for growing supplemental crop varieties. But it is important to realize that these passageways are "commons" areas. The personnel (and pioneers) will have to respect an honor system not to help themselves. And, there must be a person or group of persons who adopts each living wall and cultivates its plants.

If private quarters contain some well-lit spaces in which small private gardens can be maintained, this will provide a special opportunity for cottage industry enterprises that specialize in adding special treats to the diet.

Weekend or sunthly (following the cadence of the lunar month: dayspan, nightspan, dayspan, etc.) markets could feature both cottage industry stalls and consignment areas, where produce (and produce products such as preserves, salsa, prepared condiments, cut flowers, floral arrangements, ornamental houseplants, and organic dyestuffs) can be marketed. In this way, free time hobbies will provide a variety that could not otherwise be made available, while jump-starting an indigenous pioneer economy of goods and services.

Integrating Architecture and Life

We cannot stress enough that these developments will require a commitment to "Modular" Biosphpherics," by which the biosphere and biosphere mass will grow automatically with the addition of each new module. Yes, if we proceed with sheer physical expansion, and add neighborhood air and water and waste biomass treatment facilities as needed, we will eventually reach a population size threshold, a much bigger population and higher threshold, at which food varieties will begin to appear.

But if we adopt the Modular Biospherics plan from the gitgo, in the architecture of the first core outpost, we will be able to benefit from food and menu and byproduct variety much sooner, from the very start. The earlier constructive traditions are adopted the better.

Modular Biospherics in a Lunar Analog Station

Modular Biospherics is something that can't wait. That is why we have worked this special architecture into the preliminary planning of our own (Moon Society - NSS) Lunar Analog Research Station proposal.

Click on "Proposal Slide Shows" at the top of: www.moonsociety.org/moonbasesim/proposals/index.html

If we do not start off on the right foot from day one, the delay could easily grow to a decade or more. Of course, adopting "modular biospherics" implies a commitment to continuous occupancy. That is what we all thought was implied in President Bush's call for NASA to "Return to the Moon to Stay." Unfortunately, Mike Griffin is committed only to producing and landing a core lunar outpost that would be enduring, but not continuously occupied. But then he has also scrapped all NASA advance life support projects. Advanced = biologically assisted. Shut down are both the BioPlex in Houston and Purdue's NSCORT research program. We are clearly off on the wrong foot. This may be a gamble by Griffin to force Congress to raise NASA's annual budgets, but it is a game of "chicken" that can only lead to a program crash.

Private and Private Enterprise efforts to deploy lunar outposts are the only real hope that things will be done as they should be, and that we will locate them in an area where all the needed resources are available, not just water and sunlight, a place out of which we can rationally expand. But I digress to grind my favorite ax.

Modeling "Modular Biospherics" is the only way to test out the vision outlined above. In any open-ended modular lunar analog research station, where each module contributes something to life support, many options can be tested to see which work best, better, and good enough: graywater system options; living wall system options; supplemental food and other plant growth options.

Without a Modular Biosphere type analog station, our dreams are unlikely to come true. **<MMM>**

Making blister steel on the Moon

by David Dietzler < pioneer137@yahoo.com >

Lunar Iron Fines

Iron in pure form is not very useful. It could be used for habitat if the plates are thick, but it is to soft for any kind of machine part like gears, chains, drive shafts, axles, etc. These must be made of hard steel. Before we can have large scale ore smelting by Direct Reduction and CO recycling for iron and steel on the Moon we can get lots of iron from molten silicate electrolysis and iron grains separated magnetically from mare regolith.

R egolith is 0.5% iron grains by mass by some estimates and this iron contains some nickel and cobalt because it is of meteoric origin (1). A more recent report states that iron fines are present at about 0.15% (2). We will use the latter figure, although there may be regions in the mare where iron fines are more abundant.

Some of this iron is in elemental form and some is combined with glass in particles called agglutinates. Magnetic extraction will remove the agglutinates as well as the free iron. Grinding, sieving and further magnetic refining will be required to break up the agglutinates and separate failry pure iron grains.

A Simple Way to Convert Iron to Steel

This iron can be converted to steel by heating it with carbon for several days. Steel obtained this way is called blister steel because blisters form in it when gases escape from the coke; however, on the Moon we will by using very pure carbon instead of coke so blisters might not form. Blister steel can then be melted, mixed with flux (CaO and possibly MgO) that removes impurities like silica (left over from the agglutinate glass that might still contaminate some of the iron) to get a high quality steel. So we will be able to obtain steel before we able to build blast furnaces and CO2 recycling systems for really large scale steel making on the order of several hundred thousand tons per year for SPS, helium-3 mining machines and lunar populations and tourist resorts.

Iron from solar or electric furnaces in which the beneficiated iron grains are melted will be poured out in trenches about a foot wide, 15 feet long to get slabs a few inches thick. These slabs will then be hammered to drive out any silica contaminants and cold rolled to strips less than an inch thick. A box made of ceramic blocks from magma electrolysis that melt about about 1500 C. will be constructed and embanked with regolith. A solid ceramic lid with iron reinforcing bars and a carbon black surface will cover the box. Alternating layers of iron strips and carbon dust will be placed in the box. Solar energy will be applied to heat it up until the iron is red hot at about 1100 degrees C. Or, electric heat will be used.

At a concentration of 0.15% there are about 4800 tons of iron grains in 3.2 million tons of regolith that can be removed magnetically. Let us say simply that we want 2400 tons of steel per year. That would represent a reasonable 50% recovery rate. To make 2400 tons of 1% carbon medium steel we will only need 24 tons of carbon, so we will not starve our biospheres for CO2.

Then we need 200 tons per month or Sunth if you like that term. Two hundred tons of iron will have a volume of about 5m x 5m x 1m or about 16ft x 16ft x 3.2ft So we would need a chamber about 17ft wide x 17ft long x 3 or 4 ft deep to allow expansion of the iron and have room for the thin carbon dust layers between the strips of pure iron. Solar rays or microwaves would be used to heat this until it is red hot and the carbon will be slowly absorbed. It will take 7 to 10 days to convert iron to steel this way. Thus, more sophisticated and more productive methods of smelting iron and steel will someday be called for on the Moon.

See: The Damascus Project

http://www.moonminer.com/Damascus-Project.html

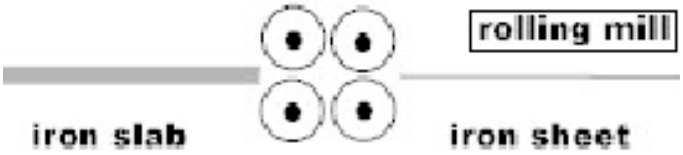
A 40 MW thermal power tower can concentrate the equivalent of 3.4 million BTUs or about 106,000 kilocalories in one hour, enough to heat almost a ton of iron from zero C. to 1000 deg. C in one hour. Some complex engineering regarding heat flows and stresses is called for to make this seemingly simple system work effectively. Don't want the ceramic box to crack!

Links to more information about blister steel

http://en.wikipedia.org/wiki/Cementation_process
http://www.tilthammer.com/timeworks/steel.html
http://www.channel4.com/history/microsites/T/timeteam/2004_sheff_steel.html

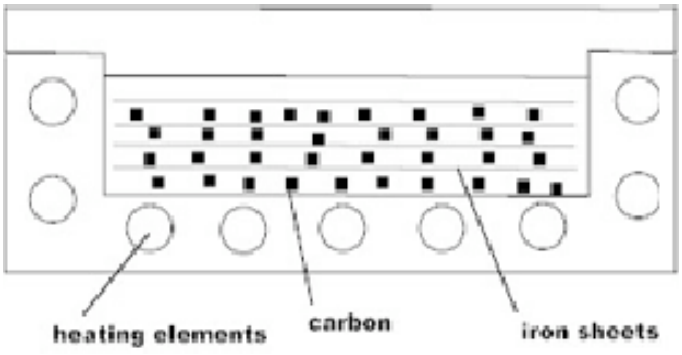
The Process is as Folows

1. Harvest solar wind implanted carbon by heating regolith. Carbon will react with oxygen in regolith and form CO and CO2 that will be reacted with H in Sabatier reactors to get methane that will be pyrolized for pure carbon black.
2. Take Liquid iron from molten silicate electrolysis and mix with free iron fines and pour out into slabs in compacted regolith molds similar to sand molds. Slabs a few inches thick
3. Roll slabs into sheets

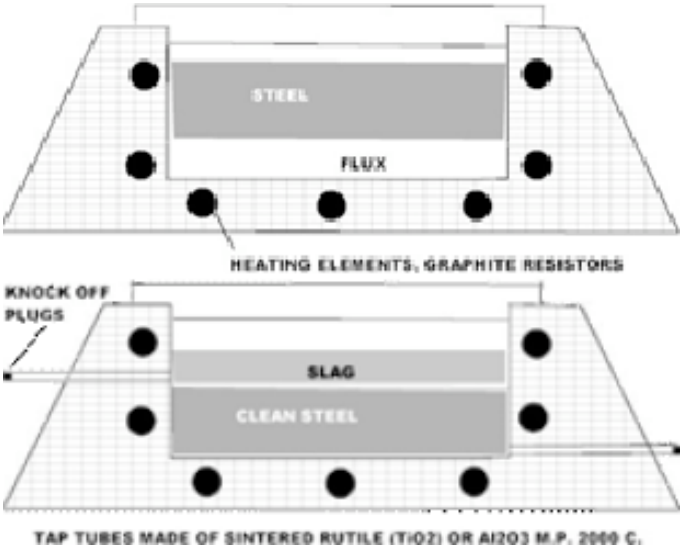


A rolling mill will be a heavy piece of equipment to upport to the Moon, but no heavier than a mining harvester/tractor, and later we will make rolling mills as well as other heavy equipment.

4. Place sheets of iron in cast basalt or ceramic block box with carbon between the layers of sheet iron. Heat to cherry red, about 1,000 °C, for 7 to 10 days. The iron will take up carbon and form blister steel. This is also called “crucible steel.”



5. After 7 to 10 days, steel will form. Use robot crane with electromagnet to lift steel out of “furnace.” Place steel in electric furnace (below) with flux.



6) Flux of CaO and MgO obtained by fluxed molten silicate electrolysis and acid leaching will remove impurities of silicon and sulfur and high quality steel will result.

Upshot

It seems reasonable that we could obtain 2400 tons of iron in the form of fines containing a few percent nickel from 250 acres mined to a depth of one meter. This would be about two million tons of regolith. At 0.5% free iron fines 10,000 tons of iron would be present, but recovery rates never equal 100% and some moondust might contain less that 0.5% iron fines. So 2400 tons is a safe bet.

Reserving Carbon for Biosphere Needs

Major objections have been raised by those who feel that steel making will deprive Moon base biospheres of precious carbon that is so rare on the Moon.

As stated above, only 24 tons of carbon will be needed to make 2400 tons of 1% carbon steel. That's a fairly high carbon content for steel. At 0.33% carbon, we would need only 8 tons of carbon per year. To protect the Moon's natural carbon resources, could we justify upporting 8 tons of carbon per year to the Moon even at $10,000 to $30,000 per pound or $160 million to $480 million??? Perhaps.

In ten years we would produce 24,000 tons of steel. How much is that? Well, the Eiffel Tower's iron structure amasses 7300 tons. So we are talking about three Eiffel Towers worth of steel in 10 years!!! That's plenty. See: http://en.wikipedia.org/wiki/Eiffel_Tower

Note: Calcium aluminate can be used as flux in the steel cleaning furnace. It could be likened to a ladle furnace. Only 10-15 kg of $CaAl_2O_4$ per ton of steel might be needed. See:

http://www.fuzing.com/vli/002021123289/HOT-Calcium-Aluminate-For-Refined-Steel_making-Fused_Type

Calcium aluminate might be obtained by solar thermal decomposition of anorthostie. See: Flux 1) Phinney et al., 1977.

http://www.islandone.org/MMSG/aasm/AASM5E.html#5e

Comments welcome as always <**DD**>

Sweet Spot for Lunar Surface Sports?

by Peter Kokh

So you want to go to the Moon for a month, long enough to experience a full dayspan-nightspan cycle and perhaps a bit more. Sure you want to explore the sheltered spaces of the settlement town, and experience the Moon's light gravity.

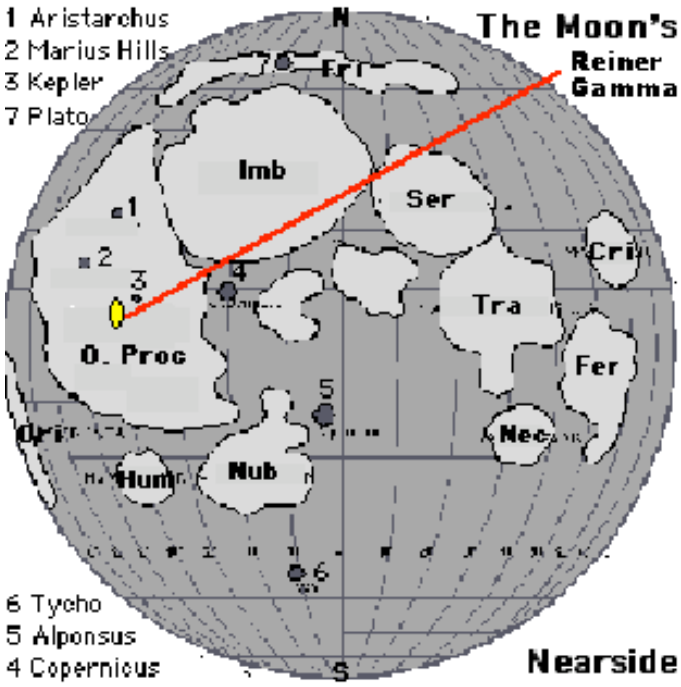
But you also want to run, romp, and play in the moondust while looking at the stars in the Moon's black sky. You want to try riding a lunar motorcycle, climbing hills, throwing a football. In short, you want to "do the outdoors" or "out-vac" as the Lunans call it, and not just the "indoor and middoor spaces" safely tucked away under a moondust blanket."

But, ...! But you could be risking your health with a little too much "unnecessary" exposure to cosmic rays. Best to limit that to necessary travel to and from the spaceport and to an outlying settlement or two.

Sweet Spot Discovery?

Well, scientists have discovered one area on the nearside that has a small residual magnetic field, an area located at 57.8° West, 8.1° North, in the Ocean of Storms Oceanus Procellarum, on the near (visible) side of the Moon, and has an extension of approximately 30 by 60 kilometers. (18x36 miles). This area is known as **Reiner Gamma.**

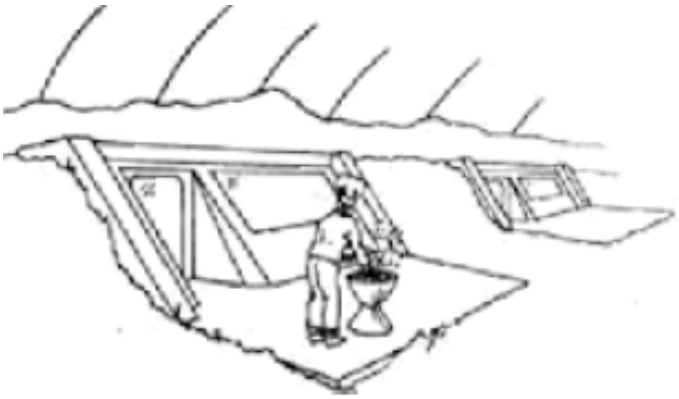
http://www.space.com/scienceastronomy/061114_reiner_gamma.html



Now the magnetic field here is weak. It would provide some protection, but not a lot. But for tourists, for whom perception is 90% of fact, this spells "oasis." Will Reimer Gamma become a lunar tourist "recreation mecca?" Will it also become a favorite vacation spot for settlers as well?

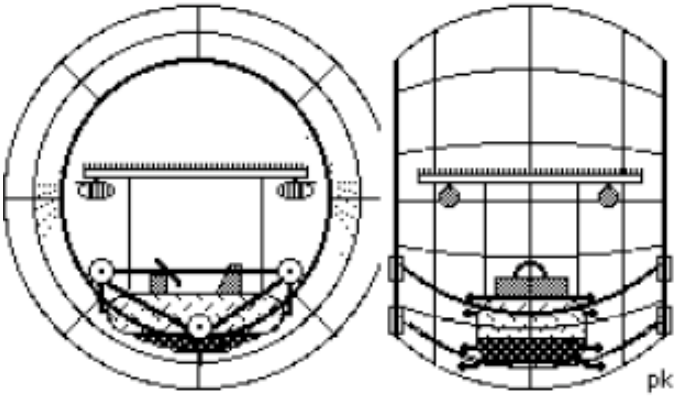
Possibilities for this "Out-vac Recreation Mecca"

Hotels in the Reimer Gamma "radiation-lite area" might sport larger windows in hotel guest suites, looking out directly over the terrain and various activity areas, as well as direct views of Earth itself 32° over the horizon.



Vacationer barbecuing on cottage patio
under glass vault to expose the lunar skies
Illustration by David E. Cremer
©1989 Lunar Reclamation Society

Various human powered conveyances, like the unicycle surrey and three wheeled low center of gravity, leaning tricycles, lighter weight, more flexible, less constraining spacesuits, observation domes, etc.

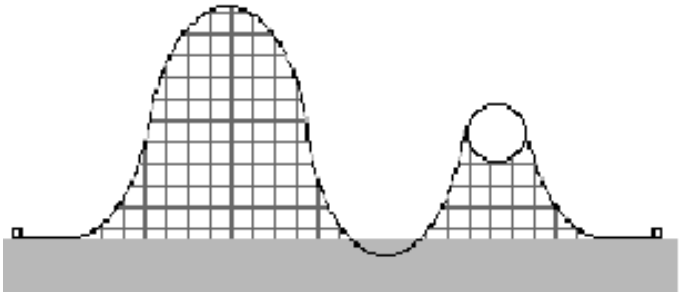


Lunar "surrey with the fringe on top"

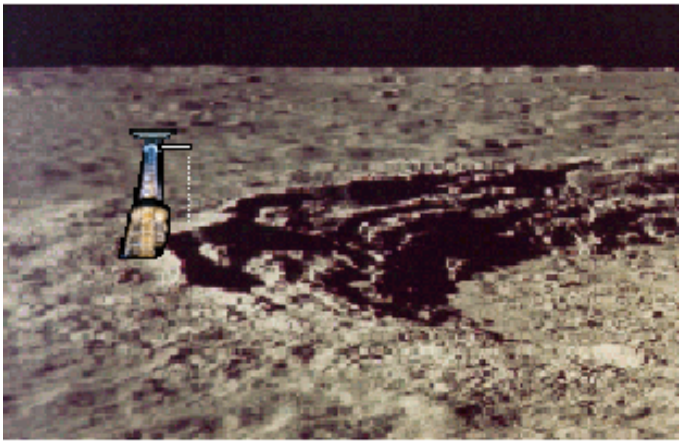
Watched *"American Gladiators"* lately? Have you seen the "Atlasball" segment? Next time picture space suited lunar thrill-seekers working their geodesic cages along a rally course of craterlets etc. Might be fun if the sweat of exertion and then overheating inside one's space suit could be handled!

Similar solar powered spheres could be equipped with a track riding buggy capable of generous side-to-side movement or banking. Such an "off-road vehicle" - call it a unicycle, an autotracker, a cyclotrack, or whatever - could open the vast lunar barrenscapes to the sports-minded "outlocks" types and help avoid cabin fever.

Heck, why not an out-vac recreation park, the kind with rides, of course. Combine low gravity with zero air resistance and greater heights! Hurtle down a roller coaster slope a hundred yards/meters high to disappear into a pitch dark tunnel and back up.?



Or doing a bungee-cord jump from a tower a kilometer high. And, of course, a lunar golf course.



Observation Towerer with Revolvinv Restaurant
at Crater edge, with bungee cord jump point
Copernicus shown, but could be anywhere

Well, maybe that's all stretching it. The residual magnetic field at Reimer Gamma may not be strong enough to warrant that much freedom in out-vac activities and exposure. But it is fun to think about a lunar oasis where one of the downers of the Moon's harsh environment is a little bit less harsh.

Confirming or debunking this Daydream

What is needed is a lander/rover to to measure the radiation flux inside and outside of this oval area, starting at the center, then proceeding to and past the edge on the shortest route along the ellipse short axis.

Would a future lunar tourist company pay for such a survey? If a billion dollar resort complex was at stake, of course! On the other hand, NASA might be interested in the data for "science' sake," and pick up some of the tab.

Daydreaming should be fun! And there is an outdoorsman in most of us! **<MMM>**

MODULAR BIOSPHERICS

V*. "Tritreme Drain Plumbing" - By separating drainage by source type, each can be more efficiently treated.

By Peter Kokh

[*Treme* (Greek) = hole] Cf. MMM #40 NOV '90, "**Cloacal vs. Tritreme Plumbing**" [reprinted in MMM Classic #4, pp. 65-66]

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

Purging ourselves of the MIFSLA habit

The "MIx-First-Separate-LAter" (MIFSLA)* attitude to waste water management" has gone virtually unquestioned since the invention of urban sewage systems in a city whose name we do not know, but whose ruins we refer to as Mohenjo-Daro, on the Indus River, about 200 miles NNE of modern Karachi, Pakistan, in 2,500 BC, four and a half thousand years ago. Another case of infrastructure being the most difficult thing to change, and thus the thing that deserves the most attention.

MIFSLA is so ingrained, it is taken for granted, almost never questioned, never thought of. "It's just the way we have always done it." How many times have you heard someone say that about something?

Waste Water treatment by Source Separation

www.holon.se/folke/projects/vatpark/Kth/guntha.shtml

On the Moon, where we are starting fresh, we have not only the ideal opportunity to do so, but an urgent imperative. Creating and maintaining a functional biosphere is daunting enough. Creating one that will keep operating as both the settlement and its biosphere keep growing ever larger.

> "The conventional waste water management system is unable to purify the sewage water to a higher grade than the nutrient content of the grey water. Biological plants are not well adapted to the purification of a mixed sewage, but if source separating toilets are used, the urine and feces could be used for agriculture, and the grey water could be efficiently purified with biological methods to a grade that it can be reused in the settlement."
>
> *Folke Günther*, Stockholm - URL above

Obviously, if we are going to build and grow settlement biospheres in modular fashion, with contributing components in each new habitation and activity module, we don't need to make it more difficulty simply for the sake of "the easiest (most familiar) way."

The MIFSLA Way of Doing (or not doing) **Business**

- Clean water is mixed with urine and feces to a polluting mixture, both regarding plant nutrients and pathogens.
- This mixture is in turn mixed with a fairly clean grey water (sinks, bathtubs, showers, laundry).
- The resulting mixture is diluted with drainage water (rain) (About 80 m3/person*year [19]) in an extensive web of piping.
- Finally, the mixture is expensively purified to a quality comparable with the original grey water, but with a doubled volume.

Folke Günther, Stockholm - URL above

Wetlands-type systems accepting MIFSLA loads do not do as good a job, especially in reducing phosphorus content, as would be possible if the differing loads were treated separately.

Common Toilets mix wastes also

In the common water closet, urine and feces are water-flushed together. But there are several designs which separate most of the urine from the feces, so that both can be treated and recycled as agricultural fertilizers separately. There are several types of composting toilets designed for off-the-plumbing-grid use, and they function well, if instructions are followed.

At the Mars Desert Research Station, the original toilet was a composting one, operated poorly, with high odor problems. This may have been the result of improper installation, but more likely was the result of higher load (more users) than it was designed for.

We personally favor the Wolverton System, in which combined urine and feces are flushed into a tank inoculated with microbes to destroy the pathogens and break down solids, the effluent feeding a runoff planters producing clean fresh odor-free air, green foliage, under sunlit conditions. Such systems are load-restricted, but if used in every habitation or activity module in a number to match expected loads, would both turn the black water into gray water while contributing to the biosphere mass and function. This seems the best match for "Modular Biospherics" that we have seen, however, improvements and alternatives are always welcome.

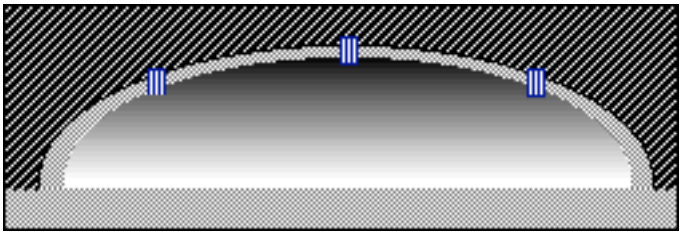
In our earlier article, written long before we heard of the Wolverton system, we suggested that toilet wastes be collected in changeable holding tanks. You would put a full one "out front" to be replaced with an empty one, by a municipal utility service. Utility personnel could make the switch in your home at an extra fee for convenience.

Separate drainage can be carried much further. Waste water from various types of industrial operations each have varying types of adulteration, each suitable for a special kind of treatment. Mixing industrial waste waters makes no sense and compounds the problems.

To insure proper installation and connections, drainage systems meant for different types of effluent could be color-coded. This is a system that we can make work. We need only the will to do it right.

Separate Gray Water Benefit

Pretreated odor-free gray waters irrigate "Living Walls" and can feed waterfalls, fish streams, fountains, and other delightful water features. The result would be a more pleasant settlement. **<MMM>**



↑ Unpressurized Out-Vac Sports Arena ↑

Sporting Activities in airless vacuum on a moondust surface in 1/6th gravity in a thermally mild, radiation-free environment

By Peter Kokh

In the illustration above, a shielded dome (it could be any architecturally practical shape capable of supporting a couple of meters~yards of sheltering moondust (as much of a load as a foot of equivalent material in Earth gravity). The dome-vault-shed could be of any size. The first one might be small, for demonstration purposes, but eventually "stadium-sized" out-vac areas could be erected for inter-settlement league team sports.

Advantages of this environment:

- It does not need to be filled with air (that much nitrogen as a buffer gas would be expensive and extravagant)
- It allows sports in vacuum, on the moondust surface, giving the authentic feel of the lunar surface, but without exposure to cosmic rays, intense ultraviolet, and micrometeorites
- It is isolated from the dayspan/nightspan cycle and is thus thermally mild or benign. Expected playing surface temperature, and temperature of the dome ceiling would be the same as two meters~yards under the lunar surface, c. -4° F = -20° C (it is better for the environment to be cooler than the players, so as to absorb their excess radiated heat.

We've seen photos and video of the Apollo astronauts, encumbered as they were by very heavy life-support packs, and very cumbersome space suits, hop and romp on the lunar surface. We wonder how high and how far we could jump, without all that excess weight.

In this more benign "lee vacuum" environment, we might have a chance to find out. Not only are the dangers of radiation, ultraviolet, micrometeorites, intense sunlight all avoided, but by raking the moondust floor free of rocks down half a foot (15 cm) we remove risk of suit and/or visor puncture. In the process, we could also remove most of the troublesome powder component if we wished.

Lighter Sports-suits

We have previously recommended shielded but unpressurized sheds for warehousing items needing to be regularly accessed or serviced as this would allow the wearing of lighter pressure suits allowing greater agility, for less tiring prolonged work activities. Let's take this up a notch. For sports activities we could wear what is called a counterpressure "skinsuit" much like a modern diving suit. It would be lighter and far less constricting of arm, leg, and torso movements.

Helmets could have more ample visors that extended the field of view to what we normally experience on Earth without any headgear. If we are going to have out-vac lunar sports, we need the right outfits.

The "moonskin" counterpressure suit made for himself by Artemis Moonbase Sim 1 health & safety officer William Fung-Schwarz. It has a light-duty backpack and it allows greater agility with less fatigue but that helmet has to go!

Supported activities

Larger shielded but unpressurized arenas would be ideal if we were to develop exciting lunar surface team spectator sports, as we will, in time. Volley Ball, anyone?

But we can also imagine a whole lineup of lunar surface track & field events from sprints, relays, hurdles, pole vaults, javelin throws, to long jumps, -- you name it.

Gymnastics too! We could have trapeze setups and trampolines to see how high we can really bounce! And why not circus type acrobatics on the flying trapeze!

The first of many

A facility like this could be created by one major settlement, with a loval settlement-wide league for team sports. But as the rules of the various games matured as we became more experienced with what we can do inside such an environment, and as other settlements grew in size, it would be sure to be copied, and become a truly lunar experience. When otherwise unused, this could be the testing ground for new moonboots, moon bikes, etc.

A must-see, must-do tourist experience

Supported activities would quickly become a signature part of lunan culture. Glass-walled pressurized areas along the perimeter would house ticketed spectators and VIPs. Events in these arenas, if they evolved to a stage were they were truly exciting to watch, might be televised to Earthside audiences by ABC's Wide Worlds of Sports on Sunday afternoons. Even tourists would want to get in on the act, using the facility when teams were not. A chance to get the full experience of lunar gravity on a somewhat natural lunar surface would rank high on the list of draws.

Unprotected Out-vac Sports

We have written previously, in several articles, about various ways the incurable "outdoorsman" might find some satisfaction on the Moon. We especially recommend the following read:

MMM # 111 DEC. '97, p 6. Opportunities on the Moon for the Incurable Outdoorsman [also in MMM Classic #12 p4]

There will still be yearning and support on the part of the more rugged and unfettered outdoorsman for sporting experience of moonscapes "in the raw." Some of these will be road rallies, long distance races over rugged courses, mountain climbing, lavatube spelunking, just plain hiking, and more. We are not all cut of the same cloth, nor should be the ways we let loose. **<MMM>**

A Spartan 11-Step Industrialization Scenario for a Lunar Mining Base

© 2007 David A. Dietzler pioneer137@yahoo.com

The late Dr. Larry Haskin wrote about **"A Spartan Scenario for Use of Lunar Materials."**

http://articles.adsabs.harvard.edu/cgi-bin/nph-iarticle_query?bibcode=1985lbsa.conf..435H

In my view, this would consist of using:

1) unfluxed molten silicate electrolysis to produce oxygen, iron, iron-silicon alloy, silicon and ceramic blocks. Silicon could be zone refined to high purity for solar panels. Zone refining does not require chemicals that must be upported [shipped up the gravity well] from Earth and will be done more easily in the low gravity and vacuum of the Moon than on Earth where it must be done in inert gas filled chambers and rods can't be too massive lest they fall apart at the molten zone.

2) cast basalt tiles and linings. Cast basalt can resist 96% sulfuric acid so it could be used to line metal cham-bers used for acid leaching of regolith, but first we must develop the base to a point at which we can make H2SO4 leaching equipment on the Moon We'd have to mine sulfur present in regolith at about 500 ppm from vast areas of the mare to make the sulfuric acid.

3) sintered basalt bricks/blocks. It's my impres-sion, based on discussion with an associate, that experi-ments were done on large cast basalt bricks or blocks and as they cooled various minerals solidified and settled at different temps, ruining their quality. However small cast basalt bricks have been made. See:

http://www.lpi.usra.edu/publications/reports/TR98-01/98-01.abstracts.pdf

BRICKS AND CERAMICS. C. C. Allen, Lockheed Martin Space Mission Systems and Services, 2400 NASA Road 1, Houston TX 77058, USA.

Thus, sintering basalt may be the better ways to make large bricks and blocks. These would be porous enough to bond with cement mortar for wall construc-tion. We must wonder how well cement mortar will hold up under the temp extremes of the lunar day/night cycle.

While indoors this might not be a problem, out vac [out on the vaccum-washed lunar surface] we might want to stack sintered basalt bricks and blocks and sinter them together with microwave heat to build radia-tion shields for habitat, solar furnaces (support structure for graphite crucibles), foundations for mounting machines, etc.

It may eventually be possible to hew large solid basalt blocks out of the walls of lava tubes.

4) Glass, fairly clear, from nearly pure beds of highland anorthosite, made by melting this regolith with concen-trated solar energy. Glass could also be made from volcanic glass deposits. It may also be possible to extrude these glasses into fibers and bind them with a glass matrix to make glass-glass composites also called GGC or Glax [Glass-glass composites].

5) Nickel. There are from 0.15% to 0.5 % elemental iron fines containing some nickel of meteoric origin in the regolith that could be extracted magnetically. Some of these iron particles are fused with glass (called agglutinates). Grinding could break up the glass and metal particles and magnets used to draw off the iron. This iron could be melted with solar heat and cast into various forms. Iron powders could be pressed into molds and sintered to make various parts.

6) Crucible steel. Iron from electrolysis and iron fines could be melted, cast into slabs in sand molds, then hammered to drive out silica, then rolled into thin sheets. The sheets would be laid in a box made of ceramic blocks from molten silicate electrolysis and/or sintered basalt with correct amounts of carbon dust obtained by volatile harvesting in between them. This would be heated to red heat. about 1100 C. for 7 to 10 days and the result will be steel. To clean it up further the steel could be melted along with some CaO flux if necessary. This steel could be alloyed with titanium and/or silicon produced on the Moon.

7) Titanium. Ilmenite (FeTiO3) could be extracted electrostatically from mare regolith and reduced with hydrogen in a fluidized bed resulting in titanium dioxide and iron. Water produced would be electrolyzed to recover hydrogen and gain oxygen. Fused slag particles of TiO2 and iron could be ground up or the iron could be extracted with acid leaching. The TiO2 makes and excellent high temp ceramic and particles of it could be sintered in forms heated by microwaves. TiO2 could also be put into FFC cells to get titanium metal and oxygen. Titanium powder could be used to manufacture all sorts of small complex parts with electron beam of laser 3D additive sintering.

8) Volatiles. *This should be at the top of the list!* Dr. Kulcinski of the University of Wisconsin and his associ-ates have designed volatile harvesting machines that could extract **H2O**, **He**, **CO2**, **CO**, **CH4**, **N2** from the mare. Solar wind implanted **H**, **C** and **N**** will react with oxygen in regolith and carbon will react with hydrogen to form these compounds when heated to about 900 C. in the miner's on board furnace. See:

http://www.nasa-academy.org/soften/travelgrant/gadja.pdf

9) Cement, concrete. According to Dr. T. D. Lin cement can be made by heating anorthostic regolith to 2000-2200 C. to drive off oxides of magnesium and iron and some silica too to increase the CaO content for cement. See:

http://articles.adsabs.harvard.edu/cgi-bin/nph-iarticle_query?bibcode=1985lbsa.conf..381L

Solar energy would be used to heat the anortho-site. Low mass foil or sheet metal reflectors could be used. Of course, to make cement and concrete we need water and that could be obtained by volatile harvesting and possibly from ice deposits in permanently shaded polar craters. Ice on the Moon has yet to be verified, and this is one of the most tantalizing indications made by Clementine and Lunar Prospector.

** **Solar Wind Volatiles** to be found in the upper meter or two of the regolith also include the noble gases: **He**lium (including the fusion fuel **He-3**), **Ne**on, **Ar**gon, **Kr**ypton.

10) Aluminum, aluminum-copper alloy and lithium-aluminum alloy from scavenged ETs or other rocket upper stages. Producing aluminum on the Moon is not simple. Purified (by heating) anorthosite must be melted, cooled and ground fine, leached in H2SO4, the Al2(SO4)3 filtered off, roasted to aluminum oxide, then electrolyzed. Fluxed electrolysis (LiF/CaF flux) of purified anorthosite can produced O2, Si, Al and Ca. These processes are complex and require equipment that must either be upported or made on the Moon, but more challenging is that they require chemicals from Earth that must be recycled efficiently. Solar carbothermal reduction of Al2O3 obtained by acid leaching is also possible and seems simpler than these other processes.

We must have electrical wires and cables. The Moon has almost no copper. If we can recover ETs (Space Shuttle External Tanks) or upper stages of a rocket like the Falcon 9 should it ever go into production, transport them to the Moon and melt them down and extrude aluminum and Al-Cu wire, we can get started wiring the Moon base. A 30 ton ET will yield a lot of electrical wire!

11) Precious metals and other materials from scavenged satellites. Orbital debris is becoming a real problem. It threatens expensive commercial and defense satellites. Any future space program must involve orbital debris removal. There are thousands of pieces of space junk from old upper stages to dead satellites in orbit.

Proposals have been made to zap them with lasers and such, but it would be better to use electrodynamic tether systems to snare these objects and collect them and deliver them to lunar orbit. ED tethers require no propellant; only solar energy. A veritable mountain of gold is already in high orbit!

The development of electrodynamic/momentum exchange tether systems would be of immense value not only for orbital debris removal but for transportation of cargos to LLO without propellant. See:

http://www.spacetethers.com/

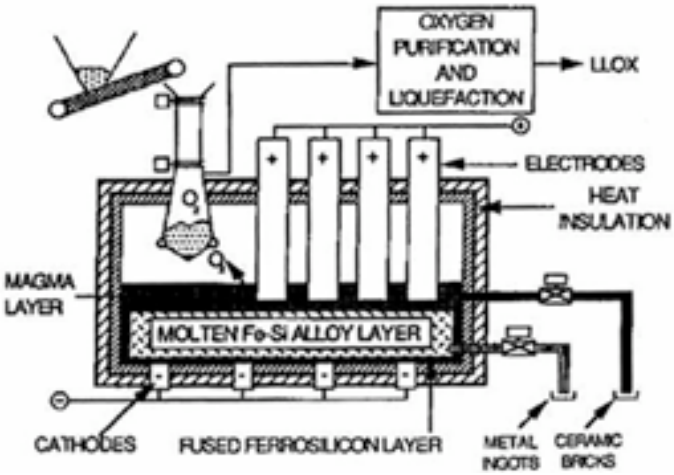
Eventually, lunar industry will progress to a point at which very sophisticated machines can be built like cascade electrostatic mineral separators, perhaps CO direct reduction furnaces that can smelt large amounts of iron from silicates, high temperature plasma separators, electrophoresis devices for extracting trace elements, even bioleaching in microbial farms under well controlled conditions.

Bootstrapping our way to More Sophisticated Levels of Industrialization

But what good are these materials? We will use them to build fleets of helium-3 and solar wind volatile mining machines, drag lines, vehicles, more processing devices to increase materials production without upports from Earth of molten silicate electrolysis units, microwave furnaces, solar furnaces, fluidized beds, FFC cells, grinders, crushers, extruders, rolling mills, tilt hammers, etc. We will build modular underground manned bases with iron, titanium, steel and glass with interior furnishings, floors, and everyday items made of cast basalt. We will build extensive solar panel farms and eventually ring them around the Moon, first at high latitudes in polar regions where the Moon's circumference is not so great, connected by calcium cables (Ca is a better conductor than copper) for constant power during the lunar day/night cycle. We will build dirt roads with bulldozers and graders built on the Moon, cut and fills into rilles, perhaps even roads paved with basalt slabs and someday even monorails on the Moon.

We will build mass drivers to launch lunar materials into space for the construction of solar power satellites, robotic asteroid mining ships and even space ship fleets for the colonization and terraforming of the planet Mars and exploration of the solar system. Some day we will even engage in megascale engineering in space and interstellar travel. The Moon truly is our platform to the galaxy.

Many Other Useful Products Can be Derived From the Molten Silicate Process



This device requires no chemical reagents and has no moving parts. Oxygen purification will of course involve a gas cleaner and liquefaction will require pumps and space radiators shielded from the Sun and storage tanks. It operates at 1400-1600 C. and produces iron, Fe-Si alloy, silicon and ceramic bricks as well as O2. To extract Mg, Al and Ca would require higher temperatures and voltages and this leads to container and electrode materials problems as the molten silicate is very corrosive.

From the MMM Glossary [a work in progress]

http://www.moonsociety.org/publications/m3glossary.html

* **upported** - shipped up Earth's gravity well
* **out-vac** - out on the vacuum-washed lunar surface
* **Glax®** - glass-glass composites

11 Steps to Early Industriaization

Unfluxed Molten Silicate Electrolysis	1	6	Crucible Steel
Cast Basalt Tiles and Linings	2	7	Titanium
		8	Volatiles
Sintered Basalt Bricks/Blocks	3	9	Cement, Concrete
Glass	4	10	Aluminum
Nickel	5	11	Precious Metals

<DD>

MAGNESIUM

Workhorse Metal for the Lunar Frontier?

by Peter Kokh

Magnesium is one of the most abundant elements in the lunar crust, the 6th most abundant element (6%) and the 3rd most abundant metal, after iron (15%) and aluminum (7%). Its powerful affinity for oxygen makes it the energizer in fireworks. We have only fairly recently learned to produce a magnesium alloys (car wheels, etc.) that resists oxidation.

From Hopper Fuel to Structural Elements

Powdered Magnesium could possibly serve as a rocket fuel for lunar surface hoppers.

For use on the lunar surface, where exposure to oxygen is minimal, magnesium, easier to produce than aluminum, might find many structural and other uses.

Cement Production

Dr T.D. Lin demonstrated the feasibiity of making lunar cement and concrete using the abundant calcium. Calcium-based cement is the basis of Portland cement, widely used around the world, and in terms of sheer tonnage, the world's number one construction material.

But long before the discovery of calcium-based cement, people were making cements made from magne-sium. And in some parts of the world, they still are. Could magnesium-based cement and concrete become a major construction material on the Moon? That is certainly one ISRU (in situ [on ocation] resource utilization) area of research that is worthy of major attention. It will be intresting to compare production costs and performance parameters for various uses.

Magnesium Oxychloride Cement

Magnesium oxychloride has many superior properties compared to Portland cement. It does not need wet curing, has high fire resistance, low thermal conductivity, good resistance to abrasion. It also has high transverse and crushing strengths, 7-10,000 psi are not uncommon. It also bonds very well to a variety of inor-ganic and organic aggregates, such as, saw dust, wood flour, marble flour, sand and gravel, giving a cement that has high early strength, insectcidal properties, resilient, conducting and is unaffected by oil, grease and paints.

http://www.premierchemicals.com/corner/articles/cements.htm

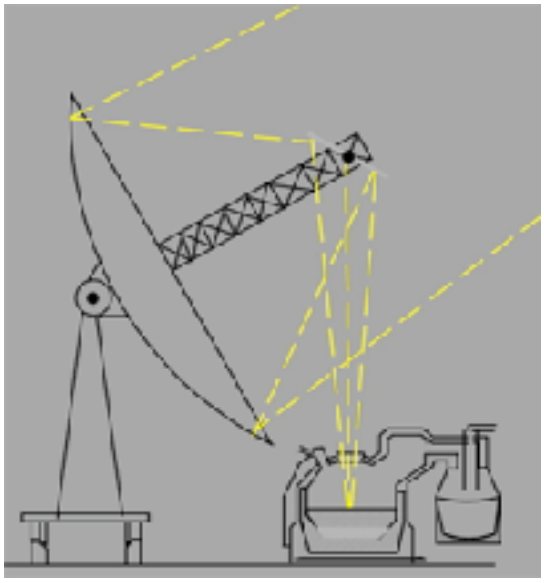
Here on Earth, *popular myth to the contrary,* production of calcium-based cement out of limestone, calcium **carbon**ate, is not greenhouse gas neutral but one of the largest offenders. On the other hand, production of magnesium cements soaks up CO2.

http://www.laleva.cc/environment/rainforest.htm

On Earth, we could see a major revolution in the works for the future.

On the Moon, this is not an issue, as calcium is not present in the form of limestone but in anorthisite minerals common in the lunar highlands. However, renewed research on magne-sium cements for terrestrial use, could help advance this technology for lunar applications. **<MMM>**

LUNAR MAGNESIUM PRODUCTION



Solar energy is focused into retort containin g Mg ore, flux and silicon reductant

Producing magne-sium on the Moon might be as simple as heating mare regolith in a solar furnace at 1500 C. and higher to volatilize magnesium oxide. In air at 1 ATM pressure MgO does not melt and volatilize until much higher temperatures; however, in the vacuum of the Moon magnesium bearing minerals will decompose and evaporate at much lower temperatures.

MgO can be used as a iron and steel making flux when mixed with CaO and it can be reduced with silicon to magnesium metal that evaporates and is condensed to obtain magnesium metal. Magnesium can be used to alloy aluminum and it might be used as an explosive when made into a slurry with LOX contained in magne-sium tanks detonated by a high energy electric spark.

Silicon for MgO reduction can be obtained from FeSi obtained by molten silicate electrolysis. Some CaO or CaO-Al2O3 flux is also required. Iron does not participate in the reduction.

What if producing magnesium was even easier? Aluminum can reduce silicon from anorthite in a lithium fluoride and calcium flouride flux (1). What if magne-sium bearing olivines and pyroxenes after electrostatic sepearation of ilmenite from mare soil that also separates anorthostie, agglutinates, etc. was done (2)? This would be followed by magnetic extraction of iron bearing olivines and pyroxene. What if the magnesian olivines and pyroxenes (forsterite-Mg2SiO4 and Enstatite-Mg2Si2O6 and Diopside-MgCaSi2O6 respectively) were simply mixed with a CaO-Al2O3 flux and FeSi and roasted with solar energy? More research must be done. **<DD>**

References:

1) Christian W. Knudsen and Michael A. Gibson
Processing Lunar Soils for Oxygen and Other Materials
www.belmont.k12.ca.us/ralston/programs/itech/SpaceSettlement/spaceresvol3/plsoom1.htm

2) William N. Agosto "Lunar Beneficiation"
www.belmont.k12.ca.us/ralston/programs/itech/SpaceSettlement/spaceresvol3/lunarben1.htms

More info about silicothermic magnesium production:
http://en.wikipedia.org/wiki/Pidgeon_process
http://members.tripod.com/Mg/mggen.htm

VANITY EXPERIENCES SERVICE

3 Hooks for Commercial Space

by Peter Kokh

VANITY Products: the piggy bank route to space

Applied Space Resources Lunar Retriever Mission

At least companies have attempted to beef up their up front capitalization by the sale of what has come to be known as "vanity products." Applied Space Services, now apparently defunct, tried to capitalize its Lunar Retriever Sample Return Mission by selling space on micro-engraved disks in a lunar time capsule called Millennial Archive. The mission was otherwise sound, in our opinion, and would have collected samples from a previously unsampled terrain (Mare Nectaris) as well as attempting to robotically improve the local terrain to make it friendlier for future visitors. More on that on an upcoming second article on "The Developer's Role."

www.spaceagepub.com/subscribers/LDarchive/LD20010319.html
www.space.com/missionlaunches/missions/moon_doggies_000918.html

TransOrbital's TrailBlazer

TransOrbital, a company created by members of the Artemis Society, also had a great plan, but similarly struggled to build up front capital with its invitation to "send your messages and memories to the Moon." This mission seems to be in limbo or suspended animation at the moment, its website not updated in three years.

www.transorbital.net/bluespartan/index.php?action=products

Bigelow Aerospace and Genesis 2

BA is also now in the vanity products business, having offered to fly business cards and other items on its recently launched Genesis 2 one quarter scale version of the large inflatable modules it is planning to launch in a few years. In this case, however, extra income is clearly not the goal. Rather, BA is endeavoring to call attention to the opportunities for business in space that its low-rent, low-lease options that will be made available by its planned first modular inflatable space station. Indeed, BA has added a twist. Your business cards, signs, logos, or whatever will be photographed floating inside the Genesis 2 module while it is in orbit - items and pictures sent up by paying participants in the Bigelow Aerospace "Fly your Stuff" program. This takes a big step beyond **recognition**.

http://www.bigelowaerospace.com/fly_stuff/

The Future of Vanity Space Products

Vanity space products have been around for a long time, if you include the "name a star for $35" schemes and the lunar land sale schemes. Experience with the Millenium Archive and similar schemes show that people would rather keep their money than insure that someone they will never know may find what they wrote or a photo of themselves ten thousand years from now on the Moon. It is not enough of a hook.

Bigelow Aerospace's approach is far better as there is timely reward: you get to see your "whatever" float in zero-G inside the Genesis 2 inflatable.

Memorials in orbit, on the Moon, and beyond

Celestis and other organizations have tried to make a buck by offering to transport a "symbolic portion" of one's cremains into orbit in a lipstick size container, for a price comparable to a traditional burial. However, one is still left with disposing the "non-symbolic" major portion of one's cremains, and with the cremation cost itself. Further, in most of these cases, the cremains portion is put in a temporary orbit that will soon decay.

Now if they would offer to soft-land one's full cremains, an average of 3.5 lbs or 1.6 kilos on the Moon in a crater designated as a memorial repository, and did so at an affordable price, that might get some business. But until space transport to the Moon is much cheaper than it is now, that's a dream for some future tomorrow. And sending one's full cremains on an interstellar journey would cost even more.

SELLING EXPERIENCES *in Space*

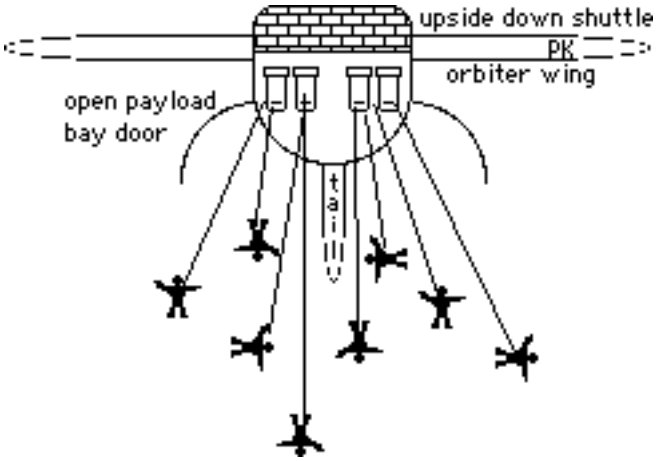
One could argue that selling the sight of one's whatever floating in zero-G inside Genesis 2 is an experience, or would be, if the one paying for it got to watch it on TV or the Internet *live.* But at least this is moving in the right direction. Experiences are invaluable. Money spent on vacations to far away lands or awesome national parks can leave a lasting impression on one's soul. We yearn to experience things that are out of the everyday routine humdrum ordinary. We yearn to experience things that previously we could only dream about. And while many of us are left behind economically, there is an almost obscenely large number of people who can afford to pay big bucks for the experience of a lifetime.

A suborbital trip to the edge of space is something that most of us realize is just around the corner for the price of an around-the-world cruise, a vacation class that is now a sustainable market. Space Adventures has now apparently sold its first $100 million ticket for a ride to the Space Station on a Soyuz, where after a week, that Soyuz will dock with another Soyuz logistics module providing life support for a week or so, and then take off for a loop around the Moon featuring a close pass over the sunlit farside. If they are smart and televise key parts of this experience, it will whet the appetite of many others. At latest count there are now more than 900 billionaires in the world.

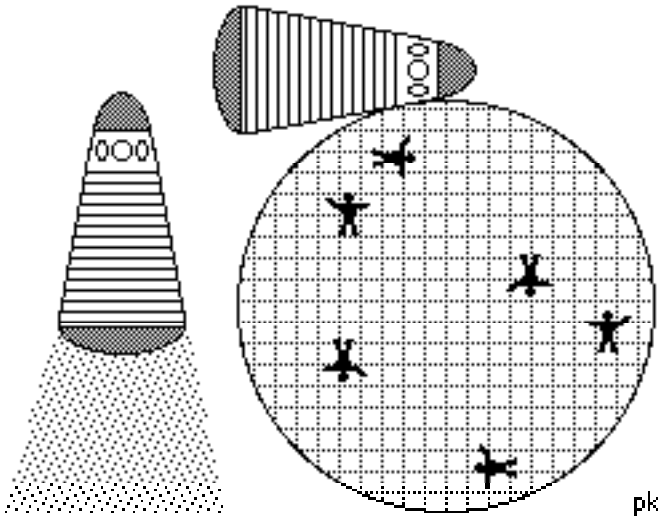
But there is potentially much more to experiencing space than just freefall and the stupendous view of Earth. Orbital Outfitters is working on a rentable pressure suit, and an inflatable raft-shield. The idea is to allow some suborbital tourists, making the ride on a space plane with an airlock, to go out the portal, inflate their raft-shield and literally sky dive from space back to Earth from a 100 miles up. [Illustration on page 14] And don't you think that in this age of Xtreme sports and rich jetsetters that there won't be plenty of takers! People are willing to pay top dollar for *extra*-ordinary vacation experiences. This is a specialty market that has been growing for the past two decades.

And while Bigelow is planning his first inflatable space station for commercial customers, there is nothing to prevent a commercial customer from leasing space for tourist experiences. See the illustrations on page 14. The true orbiting tourist hotel complex cannot be far behind.

On May 28, 1994, at the 1994 ISDC in Toronto, Ontario, the Lunar Reclamation Society Mission Control Workshops™ Team conducted a three breakout workshop on "Tourism in Earth Orbit - and Beyond." Breakout Team I under Mark Kaehny, tried to imagine what sort of tourist experiences would be possible on the first flights to orbit, before any orbiting hotels were built as destinations. Here are some of their sketches, both involving recreational EVAs or spacewalks by those tourists who were up to it.



Tether-restrained "free" floating
Space Shuttle type Payload Bay Passenger Cabin Orbiter



"Truly free" floating within "invisible" net
Delta Clipper type Passenger Orbiter shown

Once space planes start flying people to orbit, the demand for "outside" "floating free" activities will grow, and any number of thing s tried.

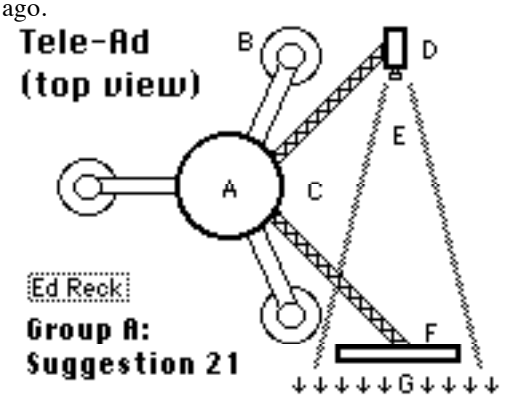
on Earth, of the Moon

But there are humbler products, more within the range of us *hoi polloi* blue and white collar working classes and middle management types. One suggestion is to land a number of teleoperable rovers, and raffle off the right to race them. When enough raffle tickets were sold, the first race would be run. Then another raffle and another race, until the rovers died. That could pay for itself, but like any game, would have a limited lifetime before raffle ticket buyers demanded a game-on-the-Moon experience more challenging and exciting.

Perhaps the simplest and cheapest "sure bet" moneymaker I have come across is the suggestion of artist Ed Reck as a participant in the Commercial Moon-base Brainstorming Workshop held at the First Contact 2 Science/Science Fiction convention in Milwaukee, WI on October 7, 1995 with Peter Kokh and Greg Bennett among leading three of the breakout teams.

Ed, part of Greg's team, proposed a simple lunar lander that would have a camera on one boom and a small electronic billboard on another, with a well chosen interesting moonscape in the background. Down to basics there would be two core components of this system:

(a) Robotic Probe - B/W Camera10 frames/sec.
(b) Signs on the Moon whose message can be telechanged from Earth, with image of sign in lunar setting transmitted to Earth - i.e. real time unobtrusive advertising on the Moon.
NOTE: This was in 1995, and what we could do with this idea today goes far beyond what any of us foresaw twelve years ago.



KEY: A. Lander core with power and communications package; B. One of three landing pads; C. retractable booms; D. videocam; E. Videocam's field of view; F. Electronic message board tele-changed from Earth; G. Background scenery.

Another idea was to draw messages on sand with a stick, and photograph these. [anything from ads to expensive but cherished Valentine Day "I love you" cards - authenticated.]

Again, this simple system falls under the category of experiences, yes vanity too. The variety of this humbler class of experiences for armchair tourists will grow even as the variety of in space experiences for those who can afford them and are willing to take the risk grows also.

But space experience need not be restricted to being a passenger. Consider working vacations! People pay good money to go on archeological digs. Others pay to man the sails on Windjammer Cruises. There is no reason why crew members of spaceplanes (hopefully, the pilot and copilot being excepted) can't go to the highest qualified bidder, including the price of training. Keeping paid crew to a minimum, and maximizing the percentage of paying crew slots, is one way to make such outings more affordable for all.

Selling "Experience" would definitely seem to be a more promising business plan component than selling vanity! And for those who can't afford to go, raffles make it possible for them to have virtual experiences at one end of a joy stick operating something actually on the Moon or elsewhere in space. And why not elsewhere? As the number of persons who become really adept at managing the 3-second time delay of teleoperating rovers and dragsters on the Moon grows, there may be some interest in seeing how far people can push tele-operation, time-delay-wise. We could invent some kind of game between teleoperable whatevers in deep space,

not on a planet, and ever increasing the Earth- arena distance and with it, the time delay to be mastered. There would be levels of mastery, with 3 seconds as level 1, 6 seconds as level 2, 12 for level 3, 24 for level 4 etc. etc. until no one could master the next delay-doubling jump. See: MMM # 131, Dec., 1999, p. 6. THE COLLOQUIPAUSE: end of conversational space.

Reprinted in MMM Classics #14, pp. 4-6] - download from www.moonsociety.org/publications/mmm_classics/

While business plans built around providing special experiences are certainly more sound than those business plans that only tickle one's vanity, perhaps the most viable business plans are built around providing services. One such plan is that of Orbital Outfitters, which we mentioned just above: they would provide suits and equipment for space-diving experiences. But that is just one example. In reality, many types of service needs are begging to be enabled.

SERVICES TO CUSTOMERS

Services in Low Earth Orbit

Services could be provided customers of ISS or other future in orbit space stations. That the ISS has been severely cut from its intended size and functions by the Bush Administration pulls the blanket from many of the business plans listed below. None of these ideas are new, many of them based on the Shuttle External Tank [see: **http://www.space-frontier.org/Projects/ET/**] but the volume of need for them, and the way Roscosmos and NASA do business hasn't left much incentive for them.

- **An orbital tug** to move satellites and other items from one orbit to another, or simply to give them a boost back up to a longer-lived orbit, including geosynch-ronous orbit
- **A fuel depot** for craft bound for GEO, the Moon, Mars
- **A maintenance and assembly garage** with parts and tools cribs and teleoperable robo-mechanics
- **A derelict satellite salvage business**. Any part or material that can be reused and is already in orbit is much less expensive than its equivalent still on Earth
- **A supplier of consumables & collector of wastes**.

Services in GEO - geosynchronous Earth orbit

GEO is getting crowded. By international agreement, parking positions must be 2° apart, meaning that there are only 180 parking spots available. Meanwhile worldwide demand is on the increase.

The obvious solution is **GEO-condominium**s, giant platforms at each slot to which an unlimited number of satellites could be attached. The platform would provide solar power, station-keeping, and communications, services that the satellite owner would purchase or rent or lease. This condominium platform idea is so obvious that it has occurred to a number of people. But no one yet has taken the plunge. In time it will become a matter of national interest, but we'd much rather see this developed by private enterprise or consortia than by inefficient socialized national space agencies.

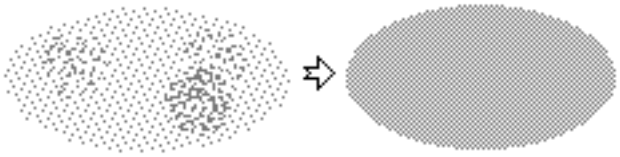
Another business plan for GEO is to **introduce space solar power by the back door, using relay sats to** beam power from one place on Earth where there is an excess to another place where there is a deficit. In other words, we would jump start solar power generation sats by simply introducing solar power relay sats.

Site Development Services on the Moon

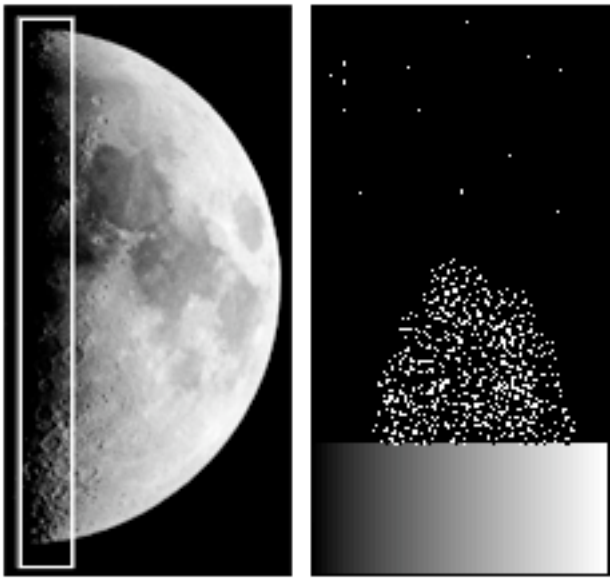
Even before the first national space agency or darkhorse commercial enterprise lands a first permanent habitation module on the Moon, there are options for private enterprise - opportunities to pave the way. Part of Applied Space Resources *Lunar Retriever* mission plan was to pre-land two robot rovers that would clear, fix, or stabilize the troublesome ultra-fine abrasive moon dust that could damage expensive equipment that might be stationed there later.

We can imagine a host of other useful services. each of them involving teleoperators on Earth and tele-operable equipment on the Moon:

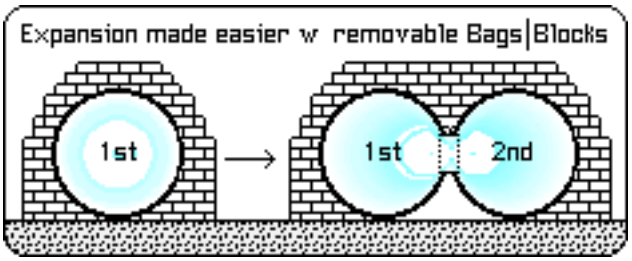
- Identifying the best area for a space landing pad to receive intensive regular usage, clearing it of boulders large and small, grading it, compacting and sintering the soil, then install a trio of transponders 120° apart along the periphery.



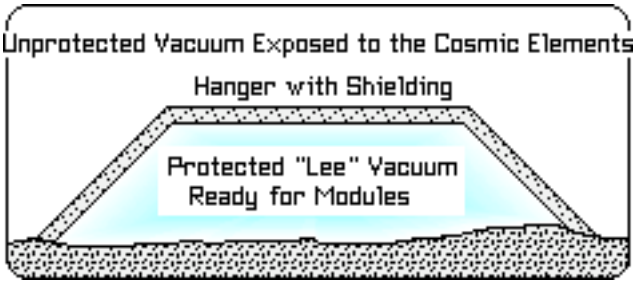
- **Also identifying the best site** for an outpost with ample room for expansion, and clearing and grading that site along with a "road" to the landing/launch pad.
- **Identifying best adjacent areas** for warehousing, solar panel arrays, and other special uses, and preparing them also.
- **Testing** how high above the lunar surface moondust is levitated as the terminators pass, of vital importance to designers of automated teleoperable telescopes.



- **Solar arrays** could be installed, complete with buried or trenched cables to the main outpost area and to the landing pad area. Then when the first habitat units are deployed they can be hooked up to power right away.
- **Manufacturing** on location sand bags filled with rego-lith or sintered blocks of moondust to be used as removable radiation and thermal shielding.



- **And/or manufacturing** of the structural elements needed to build a space frame canopy, then shield it, under which the various habitation modules could be towed and hooked up together.



All of these services could be farmed out by NASA or any other national space agency, to commercial developers.

For more, see MMM #131, December 199, pp. 10-11 "Luna City: The Developer's Role" (reprinted in MMM Classic #14)

www.moonsociety.org/publications/mmm_classics/

[All MMM Classic volumes are free access downloads without a Moon Society username and password, at the above location. Currently all the non-time-sensi-tive material from MMM's first 21 years are preserved in this archive, one pdf file per publication year.]

Tourist site preparation tasks

- **Rovers** preparing sites for Tourist Centers on the Moon could, in the process of site preparation, take photos for use in putting together Tour Guides to use as preliminary advertising.
- **In the meantime**, rovers could shoot still and moving panoramas in high resolution of any exceptional scenery around to be used as backgrounds for documentaries and science fiction films. For those old enough to remember, many a cowboy and western film used backdrop scenery previously photographed in SE Utah's Monument Valley.
- **Other scenes** worth taping are local sunrise, local sunset, and how the area looks during a total lunar eclipse as seen from Earth; any near by scarps, lavatube openings, exposed bedrock, etc.

"As long as we're here...": Secondary Profit Generators

In 2002, four members of the Oregon L5 Society NSS chapter based in Portland, Oregon, Bryce Walden, Cheryl York, Tom Billings, and Bob McGown put together an interesting list of enterprise opportunities on the early frontier. You can download this paper at:

www.OregonL5.org/docs/sr2002d.pdf

The following ideas are nearer term seeds for early lunar enterprise: (editor's selection and sequencing from a much longer list.)

- **Prospecting:** Ore concentrations (of non-primary elements) on the Moon may require actual prospecting to discover. This would be most efficiently done with hordes of small insect like rovers with geochemical sensors, with humans to follow up later on any samples "tagged" by the robot prospectors as worth a human second look.
- **Prospectors and mapmakers** should be able to sell precise ground-truth data for a price worth their time and effort.
- **Collecting Moondust .** Regular commerce will increase the supply and lower the cost. The potential market is huge, however both

  # **for pre-developers of those building and manufacturing materials** that could be produced on the Moon.

  # **and for those experimenting with Lunar-appropriate Arts and Crafts ,** *made on Earth* from returned moondust material. Later artifacts could be *made on the Moon* by crew in spare time.
- **Web-cam relays** from fixed and roving cameras might be popular, documenting the whole process of site development, deployment of first phase of the base, etc. Such films would be invaluable training tools for those to follow.
- **Entertainment .** Base crew could **hire out to terres-trial filmmakers to provide unique locations** during their off hours only, and with pre-approval.

A teleoperator DJ on Earth could select music to be played on the Moon and broadcast back to Earth, with announcements ("Our next selection is Arthur's Theme [refrain *'between the Moon and New York City'*], in honor of Mary in Manhattan who is celebrating her 29th birthday, from Chris with love")

***1. Only** those service options which do not take up crew time needed for their principal mission assign-ments should be considered, unless they lay founda-tions for a more productive follow-up mission, such as ISRU experiments, power system installations, etc.*

***2. Commercially provided equipment** should include payment for their weight and volume as these are costs of transportation to the Moon.*

Looking ahead to Moonbase Design & Operation

The authors of the paper "As Long as we're here" have recommendations for moonbase designers who by nature of their funding realities tend to be extremely conservative to the point of being "contraceptive." If we fail to allow for expansion, not only in size, but also in function, there is no point in putting up a base at all.

"Many visions of Moon and Mars bases portray small, government-supported outposts conducting pure research. Like an Antarctic base, the outpost is a drain on the economy of its sponsor."

"Space facilities should include some capacity to host visitors. Tourism support presents business opportu-nities for travel agents, guides, tour companies, housing and housekeeping, restaurants, gift shops, transportation, and entertainment."

"Many small businesses, each contributing in their own way to the economy, will be more robust, more sustainable, and more enriching than any single target business. *Planners should consider a*

community's need for small business locations and support infrastructure. Extra space should be allowed for unfore-seen purposes, and for expanding families, small businesses and tourist needs. If planners do not pro-vide avenues for growth, they may make it impossible for communities to thrive."

That's hitting the nail on the head!

Back to Vanity and Experiences

a) Auctioning off Crew Slots

While NASA may naysay any such suggestion, as a total break with the venerable history of the manned astronaut program, there is no reason why, for an enter-prise planning to deploy a commerical moonbase, crew slots could not be sold to the highest bidders ***from a select ed list of persons who paid for and have successfully completed their training***. This zeros out crew training costs, and offsets other costs by the amount realized through the crew slot auction. There is no reason to fear that crew performance would suffer if training was duly vigorous and thorough. Mission authorities could still control what crew position goes to whom on the basis of talent, expertise, temperament, and teamwork.

There is established precedent. People pay good money for the privilege or rolling up their sleeves on architectural digs or Windjammer cruises. If people would pay $100 million for a loop around the Moon tour, they might pay more than that to be on a landing mission!

After the first such mission, we might expect the money to be realized from further crew slot auctions to be less. But cutting the first mission cost is a top goal.

b) Auctioning off Naming Rights

This is something that has become quite familiar to most of us in the past decade or two. Corporations and even some individuals, pay good money to put their name on sports arenas and convention centers. Imagine an auction for the right to name the landing site? Starting bids could be preset at $100 or $500 Million or even at a Billion dollars. The right to reject some suggestions could be retained (ex. "The Adolph Hitler Moonbase") and this could be done tactfully by setting a few rules. The base, the landing pad, and the surrounding contiguous territory could all be named this way.

Lesser amounts might be realized by auctioning off the naming rights for individual modules, for the life support system, for the landing pad; even for bunks and private quarters and other "buy a brick" type fundraising efforts.

Nickels and Dimes add up

Many of us, especially those of us who have suddenly found ourselves deep in debt without ever making a "significant" purchase, have found out the hard way that petty nickel and dime purchases can add up to a hefty amount in no time. The temptation of some would be to dismiss these suggestions for fund raising. A penny saved is a penny earned, and a whole lot of pennies can become a lot of money earned. Crew spot auctions, naming rights auctions, and other humble ideas could make or break a marginal mission financially.

We remain "uppity" at our own expense.

<MMM>

Lunar Settlement has *Already Begun*

By Peter Kokh

"Say what?" "How did I miss that?" "Didn't see anything like that in the news!" Well, yes you did, if you are old enough. Now I've got you really puzzled!

If I asked you what is the very first element of a future settlement to be but in place, you might suggest a habitat command center, or a solar power array system, or a transponder to guide incoming ships to the exact chosen location. Good suggestions, and getting close with that last one.

Before the construction teams, human or robotic arrive on any scene, comes the site assessment and selection team, again robotic, human, or both. And it is all the same whether a decision is made to build a settle-ment on the visited location or not. *The scouting effort is most likely to have left equipment & other objects behind not needed for the trip back home* to Earth, or for study on Earth. "***Garbage***" and "***Trash***" protested the self-appointed guardians of the Lunar Sanctuary as the Apollo 11 ascent vehicle blasted off the plains of Tranquility to bring our first two explorers and their hoard of moon rocks back to our home planet.

Ah, the light bulb goes on! (we hope.) That so-called trash will become the most precious and valuable contributions to a future lunar settlement museum. Now you've got it! We didn't trash the Moon, we left priceless relics of our first visits.

The First Elements of Lunar Settlement are Already in Place on the Moon

They are the artifacts and other evidence of the first human scouting missions to the Moon, that one day will be held in trust by Pioneer Museums for the benefit of the Lunan Settlers and all mankind.

The hue and outcry began with the liftoff of the Apollo 11 ascent module, and continued with the liftoff's of the Apollo 12, 14, 15, 16, and 17 crews. Also of value are robotic landers and rovers that landed on the Moon. Probes that crash landed will not likely be in salvageable.

So what's the big deal? Well, it is a big deal. Some day, lunan parents will take their kids to the Luna City Museum and other museums in lunar settlements to help them understand the roots of their pioneer frontier cul-ture, the first stages in their learning to make themselves at home on the Moon, now a familiar world, no longer alien. Here they will see the first artifacts of the great, unprecedented first steps of humanity off its home world, to explore and understand a neighbor continent unto itself so different, so seemingly hostile and barren.

Museums have that power to put us in touch with forgotten beginnings, to help us appreciate just how many shoulders we stand upon, and the sacrifices and pioneering efforts of generations who have gone before us to make the life we now have possible. And this is vital for a future-looking frontier. The Moon will open the rest of the solar system someday. And keeping this march into the endless frontier rooted in the depths of the past will keep us on target, keep us human, and, as different as our life is from that of the pioneers, we will come to understand and appreciate. *It has begun!* **<MMM>**

Read "The Luna City MUSEUM Visitors' Guide 2097" in MMM Classic #11, pages 17-18.

Is that a light on the Moon?

Opinion piece by

By Charles Lesher* chuckmeister999@yahoo.com

One night in the not so distant future, Americans will look up to behold lights burning on the night side of the Moon... but whose will they be? I question if America has the tenacity to build a permanent presence on the Moon. The wars in Iraq and Afghanistan are draining our resources leaving very little for anything else and the investment in the infrastructure necessary to create a self-sufficient outpost on the Moon is substantial over many years and many governments. Budgets agreed upon in one Congress, are radically altered, or canceled in the next. I fear the first lights on the Moon will not be American. We simply do not have the political will to see it through.

Many reasonable and intelligent people ask why should we care? America has enough to worry about with problems right here in front of us. They say that money for space colonization would be better spent feeding the hungry, obtaining medical care for everyone, solving the energy crisis, and a hundred other issues that are without question, very important. I submit that this is a very shortsighted view. Space has the resources not only to make it profitable, but highly desirable, to go there. Solar energy alone could solve the world's dependence on oil. There are asteroids the size of mountains made of iron and nickel, resources we have not begun to tap and most importantly, elbow room to expand.

Earth is like a potted plant that is becoming root bound. 6.6 billion people share this planet with more arriving every day. I have read predictions that population in 2050 will stabilize around 10 billion. Others say it could exceed 20 billion. While world population skyrockets, oil dependence weakens America even as it triggers climate change and rising sea levels. Where will we find the food, water, and housing for all of these people under such conditions? How will we cope with wars fought over basic necessities? Where can we go to relieve this pressure? Humanity occupies every continent. There are no more New Worlds to explore and claim for our own. Or are there?

Americans should be aware that others are eyeing the Moon with lustful intent. China, Japan, India, and the European Union all have aggressive plans to establish a permanent lunar colony sometime in the early 2020s. Currently, America's space plan calls for a return mission in 2015 and a permanent base by 2024. Instead of properly funding the effort, the Bush administration has borrowed from Peter to pay Paul, forcing NASA to restruc-ture its internal budget to fund the Presidents directive. Planetary science missions, climate studies, and a host of other valuable and needed projects, find themselves strapped for cash or worse, canceled entirely. With the situation we find ourselves in, I have grave doubts that America can sustain the funding necessary to put lights on the Moon.

As a child, I watched Neil Armstrong and Buzz Aldrin walk on the Moon. I consumed science fiction paperback novels and was hooked on Star Trek. In the summer of '69 nothing seemed impossible and I wanted to be part of humanity's expansion into the high frontier. I believed it was inevitable. Today, I don't think it will be Americans turning on the lights of the New World and this failure will mark the end of American leadership. It will be other nations who profit, other people who push the boundaries, others who lead... We will follow...

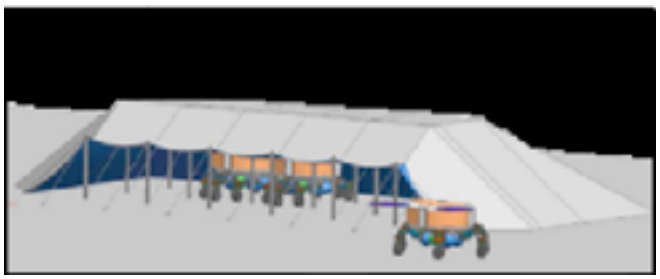
Here is where I find one remaining glimmer of hope. America is a nation of responders. We allow ourselves to be distracted until something comes along that shakes us out of our lethargy. Only then will we mobilize. It has happened before. In 1957, Americans were cruising on autopilot having won WWII, gotten a handle on the Korea War, and enjoying an economy humming along nicely. Then along came Sputnik, shaking America to its core. That night, Americans looked up to behold a shooting star in the heavens.

To some of them, this was a Russian invasion, an in-your-face threat to their way of life. America responded by not only catching up with the Russians, but in surpassing them. Twelve years after Sputnik, Neil Armstrong and Buzz Aldrin walked on the Moon. Those dozen years encompass some of the most vibrant technical growth in the history of science. America still enjoys the fruits of that labor. However, we failed to follow our success and let the achievement pass into history. But if humanity can avoid Armageddon, someday a nation will make the sacrifice and claim Luna for their own.

Until then, I visit the Moon everyday in my dreams, writing about people living in a society not yet realized. They face the same evils we face today, religion threatening to consume democracy, an American presidency in turmoil, and a Muslim empire growing increasingly strong and intolerant. They struggle through their lives and fight for their freedoms just as citizens have done throughout history. Writing speculative fiction is my way of realizing my dream, my way of sharing hope for our future.

[**Editor's note:** as always, opinions expressed in MMM are those of the writer, and not attributable to any of the organizations who produce or subscribe to this paper. The editor personally believes *Lunans should rule Luna*, not any Earth nation, not even the United States, not even the United Nations. *Settler Home Rule!*]

• **Charles Lesher** is the author of **Evolution's Child**, a speculative fiction novel about the near future, available at all major online and walkup outlets. Mr. Lesher holds a BS in Aerospace Engineering and an MS in Materials Science. Having recently joined the Moon Society, he also is a member of the Society's new Phoenix chapter, and serves as its webmaster. #####



The Concept of the Shielded Shed or Ramada

The concept, of shielding not individual moonbase modules, but one big ramada (Spanish: sun shade structure) or hanger or shed under which the outpost modules are arrayed, has also found its way into the NASA Moonbase design process.See the illustration above.

THINKING OUTSIDE THE MASS FRACTION BOX: 1

NASA's Lunar Architecture Design Goals are Good, but not quite what we need to Maximize our Lunar Presence Investment

By Peter Kokh

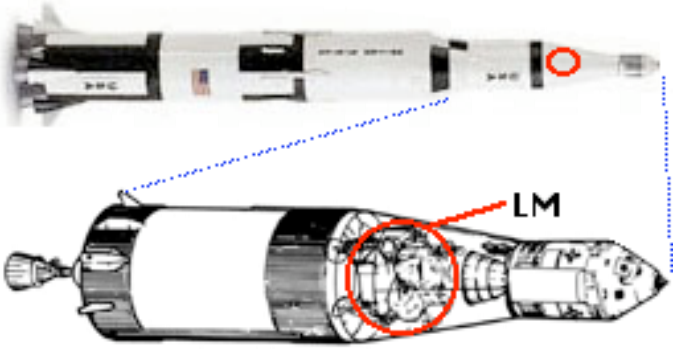
Moon Society Advisor and Videographer Chip Proser has asked me to define the steps we need to take to realize a human presence on the Moon to support a full buildout of an Earth-Moon Economy. Actually, we have talked about most of the elements and steps needed in various articles in MMM through the years.

Thinking within the "Mass Fraction" Box

But it is a very worthwhile endeavor to do the exercise afresh, and with deliberation. We'll make a start with this article, laying out basic concepts to *"really maximize"* the payload delivered to the Moon. This means throwing out the window of the slavishly worshiped law of "mass fraction." According to Wikipedia,

> "In aerospace engineering, the **mass fraction** is a measure of a vehicle's performance, determined as the portion of the vehicle's mass which does not reach the destination. ... In rockets for a given target orbit, a rocket's mass fraction is the portion of the rocket's pre-launch mass (fully fueled) that does not reach orbit. ... typically around 0.8 to 0.9 [80-90% of the takeoff mass does not reach orbit]"

The figure is even more discouraging when we are considering the typical mass fraction deliverable to the lunar surface.



The goal, adopted by NASA, to design the landing craft in such a way as to maximize delivered payload, is excellent. According to the Connally Study:

- minimize ascent module mass
- minimize descent module mass
- maximize landed "payload" mass
- simplify interfaces
- move functions across interfaces when it makes sense

Thus, by use of a minimal ascent vehicle, NASA can land a much more spacious crew cabin. *But this is still a sample of thinking within the Mass Fraction Box.*

Thinking *outside* the "Mass Fraction" Box, Part 1

When you think of it, the payload "landed to remain on the Moon" in the Apollo missions consisted only of the descent stage, and assorted equipment left behind. Not much! NASA's new "space-motorcycle"-inspired plan will allow leaving the spacious crew cabin behind. That's a big step, but still within the "Mass Fraction Box."

Our first article on "Thinking outside the "Mass Fraction Box" was "**Essays in 'M': Marshall MacLuhan: "Medium is the Messa**ge" in MMM #6, June 1987. This is republished in MMM Classic #1 - download from:

www.moonsociety.org/publications/mmm_classics/

In this article, we pointed out that the most common flaw in thinking within the "mass fraction box" was to assume without question that no part of the vehicle itself could be reassigned as "payload." We illustrate the possibilities by offering an alternate configuration for the Space Shuttle Orbiter. I urge you to download that volume cited above, if only to get this point across.

Here we are talking about delivery to the lunar surface. In that context, our quest to cheat the "mass fraction" rules drives us to make sure **that *everything that we have paid precious fuel to land on the Moon, and which will not depart on the ascent vehicle, is something that has more than temporary usefulness:*** that includes ***every part of the landing platform mass:***

- fuel tanks & descent engine & ● vernier rockets
- cargo hold & ● unloading equipment
- leg struts & ● foot pads, ● etc.

There are several approaches and types of solutions for this design challenge:

- The item can be reused as is. for example, the bulk of the descent platform, minus engines and fuel tanks, might be reused as a platform for a telescope
- The item's design could be tweaked to enable it to serve some different application, whether similar or quite different, e.g., landing struts could be assembled in line to use as an antenna mast, or alternatively to serve as part of a space frame for a canopy shed
- Perhaps part of the descent stage equipment could be designed as a mobile chassis for the crew cabin, either to taxi the cabin to its installation site, or to turn the cabin into a pressurized lunar surface bus.
- The item could be forged of a material invaluable on the Moon, such as lead, copper, brass, or stainless steel; some components, for example shipping stuffs, could be made of reusable plastics, or compressed biodegradables rich in nutrients scarce in the regolith

You get the idea. See "Stowaway Imports," in MMM # 65, May 1993, republished in MMM Classics #7, downloadable from web address above.

We would be delighted to see the NASA Moon Lander Office adopt these design goals also. This is not a new philosophy. Poor people are known to use all parts of a slaughtered pig "except the squeal!" NASA should and must adopt a "we are poor" posture, in the sense that the agency will never get all the money it might want and must learn to make do with what it gets. And to do that successfully, means not to cut this and that, that's a petulant knee jerk reaction, but to exercise maximum resourcefulness. Use everything twice!

Note that our subtitle *at left* reads: "Thinking outside the "Mass Fraction" Box, **Part 1**" We hinted in our reference to the article from MMM #6, that the launch vehicle itself, *and every stage of it,* can be redesigned to add *more* to what lands on the Moon and **contributes to the buildup of the lunar outpost/settlement.** We'll leave you with that thought until next time. **MMM>**

[Guest Essay]

No, Earth is not Enough!

By Paul Swift pswift@shaw.ca
Calgary, Alberta, Canada

An Alberta Morning

This morning as I walked to work I perceived that everything was pink. No, my eyes weren't bloodshot; the sun was about to rise above the horizon but had not yet done so. The clouds to the east were long streaky things, originating somewhere beyond the horizon and sweeping upwards to the right and across my field of vision, yellowy where the sun was about to broach the surface and a musky pink or peach color as they stretched overhead, like a cat extending in length during its morning yawn.

The heavy pink emanating from the static sky transferred itself to everything around me, the gray concrete sidewalk, the darker asphalt roadway, the sides of the buildings, even my clothing. The air itself should have been pink, too, but of course was crystal clear.

Sometimes we space enthusiasts are asked why we want to go out there and experience being on another planet when all we need and want is right here. Why waste all the time and trouble and money to risk our lives getting to somewhere we know little about, save its hostility? Why not luxuriate in what the Earth has to offer, like that magnificent rose-tinted prairie sunrise I witnessed today?

My leanings towards gaining knowledge may not encompass that which is termed scientific. Natural Science I do love, but like all individuals, I tend to narrow my focus on a very few aspects of life. We could go and examine our lists of preferred interests, and yours and mine would, almost by definition of being human, be different. It is true that our own planet is utterly amazing in its breadth and scope of engaging attractions, and that any normal person should be satisfied to seek and gather the multitude of aesthetical, sensory, and spiritual revelations that are all around us.

This Amazing Earth is not enough!

But no, I must respond, it is not enough.

I can walk or drive here and there and take in the scenery and the atmosphere of a place. Or I can fly to some strange and perhaps exotic locale and taste that part of the world, and try to do that as often as the exigencies of life permit, but the rest of the universe is cut off to me. We clever humans have devised bicycles and cars to drive and aircraft to fly, but no device yet that will assist our going 'out there'. If I wish to be amazed at the sight I expect to see approaching Phobos, the inner moon of Mars, I need a man-made vehicle to do that. I do wish to be amazed, so I and you and we had better knuckle down, put the wishing on the back burner, and get to designing and making whatever it takes to get out there.

Yes, we must spend big money!

Yes, Senator Carbunkle, we do intend to spend several hundred billion dollars on getting this to happen, and yes again, it's all so any of us can watch a pink sunrise on Mars or pick your favorite scenario.

Being a foreigner, I should keep my opinions to myself about where the money gets allocated from, but as to where it goes, I think it is fair to all, even the Senator from Porkland, that not one penny need be spent outside of the country if that's the way you choose to go. Every cent goes to your own engineers and scientists, your metalworkers and software architects, the project managers and assistants, the tradesman who fabricate the facilities and equipment on Earth, and to the other hundred thousand people earnestly employed on creating the industry of the future.

Is Change too fast?

Some people are concerned about rapid change. I think it's fair to say that we're in the middle of change, and will be in that state for some time to come. How rapid it is, and to what level we demonstrate concern are open to debate, but another interesting effect is taking place. We ourselves are changing. What we saw as novel fifteen years ago like brick shaped cellphones is now laughable. Now they are compact and ubiquitous. Every second person driving, walking, or eating has a miniaturized communicator welded to their ear. Today's cell phones have video cameras in them, Global Positioning System receivers, email, mp3 players, streaming broadcast video, address books, schedulers, and alarm reminders to brush after every meal.

Technical advances preclude our cultural changes. We get a new toy and our lives rotate on an updated axis. In the western world, or to be more correct, to anyone who can afford the new toys, it's almost a game to see how fast they can keep up with the latest info, communication or entertainment audio video development.

And we are almost at the point of the 80's brick cell phone in space tourism. People are being brought closer to the distant, the exotic, the formerly unattainable, engaged in close-up on their fifty four inch plasma screens, and they want the real thing. Now several startups are throwing hundreds of millions at designing suborbital ships for the well-heeled, and this will be the complete brick. Just like the cell phone became smaller, cheaper, faster, more reliable and more widespread, the tourist in space will find what they expect to find: beauty, excitement, stimulation, and an experience that can be shared with those who will listen.

How long will it take?

It took a hundred odd years for the average citizen to be able to tour Central Africa with the same level of interest and discovery that Livingston demonstrated in the 1860's. Let's hope it doesn't take quite another hundred to walk on the Moon like the dozen who first did so almost forty years ago.

In a rather surprise move a couple of years back, George bush announced his Vision plan, and now the hardware is being cut for the early phases of that substantial venture. The Space Station will be completed in a few years. The orbiting hotel people are peeping out of their nests, and I suspect Cyrano de Bergerac is considering a comeback.

Even now, and soon

If I overpay some shrewd entrepreneur I can get a week's training as a fighter pilot and get to soar to over eighty thousand feet in a Mig-29. The X-Prize has been won; both the X-Prize people and NASA are being innovative in offering prize money for the next of several plateaus, and those who would take on the challenge have my deep respect. All of this indicates to me that someone in the not too distant future will in fact be able to view a Martian moonrise and enjoy what I suspect will be a very moving spectacle.

The 'not too distant' future is still a few decades away. But as our culture has adapted quickly to cell phones and instant messaging, as we approach those decades, our space entrepreneurs and governments will have accomplished tasks in near Earth space and in the solar system that will make those in generations to come not only take it in their stride, but expect it.

A personal frontier journeys

When I was a bit younger my profession was that of helicopter pilot. For about fourteen years I followed that interest and it took me to some phenomenal places and afforded me the opportunity to meet some engaging folks. These are the people who populate our own frontiers. All my flying except for a little forest fire fighting was in the northern parts of the Canadian provinces, the Yukon and Northwest Territories, and the Arctic. Here the surveyors, geologists, biologists, and the bug people come to find out what makes this part of the world tick. Ok, entomologists.

The campsites and living conditions were sometimes a little crude but we were all in the same boat. This was all before satellite communication and GPS and the widespread use of computers and cell phones. We had no newspapers and no AM or FM radio that worked, but the camps usually had some contact with the outside world by single sideband or shortwave radio. We worked with what we had.

Primarily, what was at hand then and basically unchanged even until today was the helicopter. It was a three dimensional relocation device. There was never any question of making a trek or traverse across the forbidding terrain when the purpose was to ***be*** somewhere to check it out. Often a team would be positioned at a starting point with the arrangement to pick them up at a place they would work along to in the course of their sampling or mapping. As the operator of the 3-D relocator (the helicopter) it was my responsibility to ensure the safe return of the crews to base camp every day, and to do so for months on end.

On Lunar & Martian frontiers it will be the Same

On the Moon or on Mars, the same type of activity will occur. These same professionals will perform the work they do best at sites carefully chosen from the available data either before they depart from Earth for the place or once they arrive. With a limited window of opportunity in almost every case, each explorer will want to maximize their field time and cover as much as possible during their stint on the planet. So I can envision a vehicle for use on the Moon and on Mars to fill this role of three dimensional relocator.

Since the atmosphere of Mars is quite thin, about the same as Earth at 110 to 120 thousand feet, in some respects a relatively low speed vehicle could be designed that ignored the effects of atmospheric lift and drag. Such a design would be ideal for the Lunar environment as well, there being no air whatsoever to impinge on a flying structure.

Its about how we humans will evolve

But my purpose in this discussion not so much about the specific design of transportation mechanisms, nor even about exactly where and why we might employ them, as it is about the opportunity to see ourselves evolve. Who we are is to a large degree dependent on what tools we have and how large our scope might be. If we have no horses on the prairie and never travel more than a few hundred miles, even from generation to generation, we are different than our fellow human beings who have sailed around the world and encountered peoples and customs strange to their own. The world traveler is different when he or she comes home. They have grown; their perspective is broadened; they are not who they once were.

It is this evolution of perspective that we need. We need it for our self preservation and we need it to become, in some future not all that distant, more than whom we are now. A few of us have ventured into the blackness of that void beyond Earth's close embrace, and some have even walked on the surface of the Moon. Back on Earth, these people today still go to their jobs, take on tasks, wear suits and ties like you and me, and wonder sometimes, I would suppose, if they have really in any way become someone they were not before their great venture. My guess is that they have.

My Aunt Isabel once remarked to me when we were discussing maturity and growing up that she had never in her life actually met any man she considered to be mature. On her scale of what constitutes being 'grown-up' as an adult, I can say now that for sure I'll never get there either. Every day in a hundred ways I know I've said something silly, acted irresponsibly, failed to be brave enough to take certain steps I know I must take, and generally fallen short of being that person I could be. It is a great notion to think that a human being can evolve to be a better representative of this species, and that one of those ways is to be away from here to enlarge our point of view.

I could live on Alpha Centauri for a decade and fight the momraths of Callisto for the right to open a trading post by the gates to the Milky Way, but I know I'd never become that mature person my aunt found so elusive. It may be or never be (who are we kidding?) but one thing is for certain: my scope of operation and grasp of the breadth and depth of the universe would be forever changed, and I would be changed. And it is for that reason alone that this singular idea of being off-planet and of having my perspective altered has captured me.

The science to be done off-planet is prodigious; the aesthetic appeal of off-world landscapes is intriguing; the commerce to be established literally escapes pecu-niary definition; but the evolution of each human being who embraces the cosmos is the greatest thing to look forward to.

<PS/MMM>

* **Paul Swift** is head of the Calgary Space Frontier Society, a member of the Canadian Space Society, and served as Chair of NSS' 1994 International Space Development Conference in Toronto.

Extending the "Virtual" Dayspan

15.75 d 15.75 d > 24.6d 4.9d

to 5/6ths of the lunar day/night cycle at a high latitude Lunar Outpost

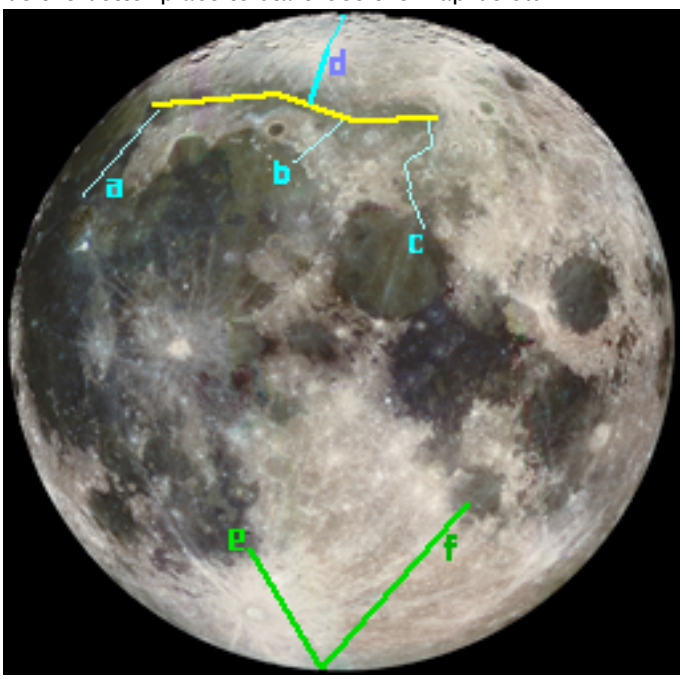
while making a major start on a global surface transportation-communications-power grid

By Peter Kokh

If it is fortuitous that there is a peak or crater crest at the Moon's South Pole that receives sunlight 70% of the time, *it is equally fortuitous* that just 600 some miles south of the North Pole, there is a long smooth mare stretching 1,300 miles East-West (at that latitude, some 120°) – **Mare Frigoris** – The Sea of Cold.

Placing Solar Power Stations at either end of Mare Frigoris would effectively extend the amount of time that full power was available to any outpost along the length of this grid to a full 5/6th of the lunar cycle, which is tantamount to having the services of the Sun for 84% of the time. *That trumps the situation at the South Pole.* And it has the enormous fringe benefit of putting in place the start of an extensive nearside transportation-communi-cationspower grid interconnecting the nearside mareplex.

If we truly want a global presence, then with all due respect to the overwhelming majority of Lunar auth-orities on the South Pole bandwagon, Mare Frigoris may be the better place to start. See the map below.



KEY: at top, is sketched the path of the East-West power grid through **Mare Frigoris**, roughly 60° north latitude, spanning 120° and 1,300 miles or 2,100 km. Shown are *easy terrain routes* southward: **a** through Sinus Roris (Bay of Dew) into western Oceanus Procellarum (Ocean of Storms); **b** through the Alpine Valley into Mare Imbrium (Sea of Rains); **c** through Lacus Mortis (Lake of Death into Mare Serenitatis (Sea of Serenity). **d** the short traverse to the north pole, some 600 miles or 1,000 kilometers *as compared to* the long traverses from the South Pole to the nearest mare coasts, **e** Mare Nubium (Sea of Clouds) 1,100 miles or 1760 km, and **f** Mare Nectaris (Sea of Nectar) 1,340 miles or 2,150 km. From the north coast of Mare Frigoris, it should be necessary to traverse only half the distance to the North Pole to encounter craters of 20 km in diameter or more where the southern portion of the crater floors are permanently shaded cold traps, possibly harboring ice deposits. For more on this assertion, see:

http://www.psrd.hawaii.edu/June03/lunarShadows.html

We reported on this in MMM #167, August 2003, p. 4, "Mare Frigoris Base Site Looking Better: Ice at the Moon's Poles Extends to Lower Latitudes than Expected" – reprinted in MMM Classic #17, p. 35

How it would work

First, we would select a location for our initial outpost at the best "junction" site to allow the easiest cross-highland traverse to the North Pole. From that point we would lay down power transmission cables, trenching them into the regolith, both westerly into northern Sinus Roris to about 75° west, 55° north, and then easterly through Mare Frigoris to about 47° east, 57° north. Say for example our "junction" site main outpost was at 30° west, 64° north, just east of crater Fontenelle, the sun would rise over "Eastpoint" east some 77° or about 6.5 days before sunrise at North Junction. An expandable solar array grid at Eastpoint would begins supplying North Junction with power from that point. At the opposite end of the grid, Westpoint, some 45° west of North Junction, a similar solar array farm would supply North Junction with power for 3.7 days after local sundown. This would virtually increase the length of available "full dayspan power" another 10.2 days for a total of 24.6 days or over 84% of the lunar dayspan-nightspan cycle. The period for which power would have to be stored, would shrink to just 4.8 days as compared to well over 8 days at the South Pole.

The key is how close to the pole this grid would be. The same length of grid that at 60° N spans 120° East-West, would, at the equator, span only 62° – the amount of coverage increases with the degree length, not the mile length. In contrast, the best you could do in the southern hemisphere would be to set up an E-W grid through Mare Humorum (Sea of Moisture) and Mare Nubium (with some difficult terrain in between) that spanned some 700 miles (1,100 km) or 37° at an average latitude of only 23° south, providing dayspan-level power for 60% of the time, or 17.8 days. Someday, an equatorial grid through the nearside mareplex would provide full dayspan level power for 91% of the time, leaving a nightspan-level gap of less than 3 days.

"Extra" Costs of this E-W Power Grid

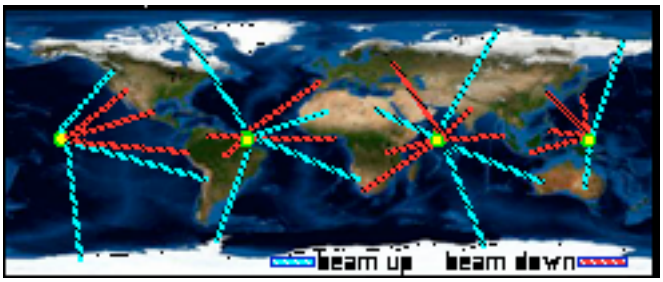
Of course, creation of the grid would require

a) two extra solar power farms, and

b) 1,300 miles of power transmission cable, and

c) the equipment needed to lay and trench the cable.

All the same, this scenario allows us a better chance to start our lunar adventure right, headed towards global occupancy and global access to resources. It puts the outpost where it needs to be, along a mare/highland coast. In contrast, the South Polar gambit risks becoming a dead end *for the sake of convenience.* **<MMM>**



WWOG - World Wide Orbital Grid

Space-Based Solar Power: Another Route

By Peter Kokh

Ground-Solar helps, but can never be enough

Space-Based Solar Power, or Solar Power Satellites combine two technologies: solar collection in space, and power beaming. The advantages of collecting solar energy in space are clear to anyone who has looked at the numbers. Yes, we do *also* need to greatly multiply the use of ground-based photovoltaic and other solar energy collection systems. But we would have to quite literally pave over the state of Arizona and much of neighboring states with solar panels to supply the national power demands, and the real estate costs of that could be higher than the up front costs of space-based systems.

Yes, we need to continue to make homes and all other structures more reliant on a combination of energy-saving construction methods and architectures, and on site energy generation. The more individual home and building owners do their part, the better. But a plan that counts on widespread support by individuals facing their own microeconomic facts-of-life is not a plan at all for a national, let alone a global, approach to replacing dirty energy generation systems with clean ones.

The Long Lead Time Hurdle

The problem with space-based power generation schemes is that as much sense as they make, they will decades to put in place. That long lead time may be enough to discourage many and send them looking for second best options that can be put in opera-tion in shorter time spans. It would be tragic if the Space Based Power strategy called for by National Space Security Office, is not pursued because supporters want all the plan, when in fact there is a nearer term option that could be very attractive, cost far less, and yet guarantee that the full plan be eventually realized.

Divide *and Conquer!* We suggest that we concentrate on the most basic half of the plan: *power beaming, not just from space, but to space.* This would require rectennas in both orbit and on the ground. It would require considerably less tonnage of material for construc-tion, a threshold that could be met by launching all the components from the Earth's surface. Why?

Detractors of Space Based Power Generation Systems number not only Mars advocates who disingenu-ously want to dismiss and discredit anything that may legitimize a return to the Moon and lunar industrializa-tion, but vested interests in terrestrial power genera-tion systems: coal, oil, gas, even ethanol. But this same unholy alliance would be all in favor of the establishment of a single world wide power grid, where excess power from anywhere could be beamed to space and relayed to wherever it was needed.

In other words, let's concentrate on the creation of a space-based world power grid first. Oil people, tar sands people, coal people, hydroelectric people -- they will all see the sense of that. The effect would stabilize world economies and greatly level the economic playing field, benefiting developed and developing nations alike.

At the same time, we will have put into place an orbital power relay system, that when the shortages that come from uneven distribution of fossil fuels and other fuels can no longer be managed by shifting loads because the total amount of terrestrial power generation is now insufficient, you just need to add solar arrays to these orbital relay stations to tap a bottomless supply of clean power. See the NSSO quote on page 2, column 2. That the orbital worldwide power grid is in place will easily derail any further opposition to "out-sourcing" additional power generation to off-surface locations, made economically feasible by the use of lunar materials.

Wireless Power Transmission is Demonstrated

On June 5, 1975, NASA successfully beamed 34,000 watts (34 kw) of power from the Goldstone Dish over 1.5 kilometers (0.9 miles) to a JPL-built rectenna on the Goldstone collimator tower on a nearby ridge -- *at more than 82% efficiency!* Watch this 2 minute Video: www.youtube.com/watch?v=jd47JXuz0g8

The WWOG could help now, in the interim, not only by shifting excess power, but by connecting to unused power sources.

We believe that since it does not require compo-nents made on the Moon, a World Wide Orbital Grid could be put in place in less than half the time needed for realization of Space Based Solar Power systems, *without detouring or delaying the latter.* Quite to the contrary, this phased approach would speed up full realization of the SBSP plan by effectively disabling opposition by the powerful vested interests of Coal, Gas, and Oil producers. Here is how WWOG would help:

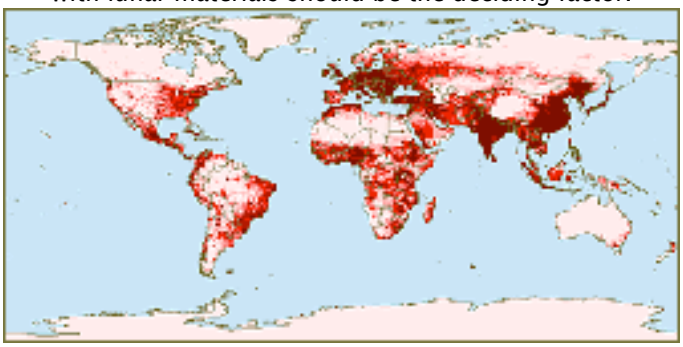
- shift power loads globally rather than on the present subcontinental basis, with much greater flexibility of sourcing. Excess power from *Hydro-Québec* could be beamed to India as easily as to Arizona instead of just to the US northeast.
- Regions with chronic power shortages and no nearby sources of surplus power would find quick relief.
- Areas with fossil fuel reserves, instead of shipping those fuels (before or after refining) could derive added sales value by generating needed electrical power and exporting that by the WWOG instead of via pipelines and tankers which have environmental risks.
- Areas with little domestic power need but great capa-city to produce power would now have a major export market to catapult the local economy into the new integrated world grid. Four examples:
  - # Underpopulated Desert areas without fossil fuel reserves but with abundant sunshine/wind.
  - # Antarctica: wind farms emplaced along it's 360° circling coast could beam power to power-hungry areas, without negatively impacting the Antarctic environment. Antarctica has the world's strongest, steadiest winds constantly blowing in the same direction, northward, away from the south pole. This power source is now untapped.

There may be similar steady winds buffeting the arctic coasts of Alaska, Canada, Greenland, Scandinavia, and Russia-Siberia

OTEC (Ocean Thermal Electric Conversion) units anchored off the US eastern seaboard in the Gulf Stream could supply abundant power to wherever needed. The Japan Current could be tapped also.

In short, not only would the WWOG even out power distribution globally, and with it level the economic playing ground, but it would tap considerable energy sources not now in play. This would help ease us through the period of two or more decades before a Space Based Solar Power Grid could be put in place, piggybacking on the already established WWOG. It is a win-win situation.

An orbiting solar array design currenty highy favored. How well a proposed design lends itself to construction with lunar materials should be the deciding factor.



Global Population Density Map. With a World Wide Orbital Grid, power generated in unpopulated areas, including arctic regions, could be beamed anywhere.

Phasing in Space Based Solar Power with WWOG

- If we can't have our cake with frosting, let's push the cake by itself. In time the frosting will be added. The alternative is that we get nothing, the world sinking into energy wars and general disorder and chaos.
- The WWOG builds on existing power generation systems, their present location, the needs of under-developed and developing areas, meshes well with world economics, will have the full support of power generation companies, and will create a new level (double entendre) of international cooperation.
- That's a plan that doesn't have to wait decades before results start justifying expenses.

How do we start? There are several unanswered questions about power beaming through the atmosphere and to and from space. These questions concern efficiency and best choice of wavelength. safety for humans, wild-life, vegetation, and livestock. We need a to investigate these uncertainties and zero in on the best options.

Then we build an orbiting rectenna and power beaming relay demonstrator, and if it passes muster, put it in operation in an area of that includes regular power need/supply inequities, both deficiencies and surpluses. Then we ramp up to mass production of these units and their deployment to create the WorldWide Orbital Grid.

Getting Everyone to "Buy In" Along the way, we create a consortium of power generation companies and grid managers who want to be involved. Pair them up with developed and developing nations that see the WWOG as in their best interests and establish **a WWOG Authority** representing all these players and interests.

Finding investors is crucial. The members of the WWOGA (individual power generation companies) can place surcharges on their terrestrial power customers to help support expansion of the WWOG. Power generation companies with unsold excess capacity should be quick to invest as a way to maximize their profits and grow their power generation capacity.

No part of the inhabited or uninhabited world (not even the deep Arctic and deep Antarctic, from where orbiting relays may at times be too close to the horizon for effectve beaming) will be too remote to benefit. Power will be available not just to cities and manufacturing complexes but to agricultural and other areas: for irrigation and seawater desalinization, etc. Teleoperated nuclear plants could be established on remote uninhabited islands, to contribute to the grid. In general, establishment of a WWOG will lay economic grounds for would peace and prosperity. widespread economic well-being,

Of course, it does not stop dirty power generation or start regreening the Earth, but by laying the natural foundations for SBSP while disarming all opposition, it will bring the day of a prosperous cleaner and greener Earth that much closer, as well as make more inevitable the establishment of an Earth-Moon economy.

Meanwhile ... There is much we can do in America and else-where to slow the growth of dependence on fossil fuels for power generation. We can do much more in the way of on site solar power generation for home and building use -- *and not just in the sunny southwest!*

"When you look at solar usage, the US is currently third behind Germany and Japan. Both of these countries currently have the solar footprint of Northern Michigan, but they are both able to make solar power work for them." - www.altenergystocks.com/archives/2005/10/

By doing as much as we can with ground-based solar, we will not only be buying precious time, but we will be easing the public mentality towards a wold view in which solar energy is King. That will help weaken the influence of the Vested Interest coalition of oil, gas, coal.

Action Item I will be presenting these ideas to the National Space Society Space Solar Power committee for consideration. Dismissing this phased in approach in favor of going for the whole plan or nothing, involves the higher risk of failure. We need to avoid swimming upstream when there is this sure fire phased in plan that all interests involved will accept much more readily. And, though it is not much mentioned, a Space Based Solar Power system that does not aim at a World Wide Power Grid will only exacerbate the divisions in the world which motivate unrest, conflict, and war as well as unacceptable inequities. We are all in this together. There is no "American" solution, only a world wide one. **<pk/MMM>**

THINKING OUTSIDE THE MASS FRACTION BOX: 2

Improving on NASA's Lunar Architecture Design Goals

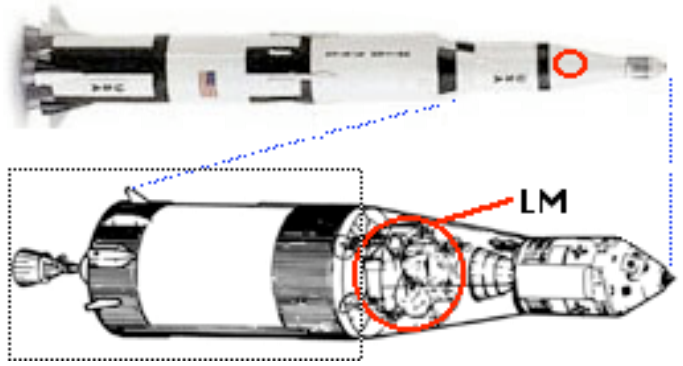
By Peter Kokh

In the first installment last month, Part 1, we talked about making maximum use of everything landed on the Moon. That way *everything we land on the Moon* becomes payload delivered, *not just the crew and cargo.* Let's carry the argument further.

The Translunar Injection Stage as a Deliverable

Any part of the Earth Orbit <> Lunar Orbit ferry vehicle that delivers the landing craft to low lunar orbit for its descent to the Moon's surface, *which is not needed for the return to Earth orbit* can be delivered the rest of the way to the lunar surface at little extra cost. What things this may consist of depends on the vehicle's design. Expended fuel tanks (unless they are refueled with lunar liquid oxygen) and farings are two obvious suggestions. Of course, this implies that these items can be replaced in LEO for the next trip out to the Moon.

In Apollo, the Saturn 3rd stage that brought the LEM and Apollo Command Module was effectively tossed overboard, left to crash on the Moon. (area in dotted box)



Saturn SIVB *left* **SIVB Adapteer Skirt *right***

http://en.wikipedia.org/wiki/Saturn_V#S-IVB_third_stage

The SIVB: 58' 7" [17.85m] tall/long; 21' 8" [6.6m] wide, such a volume landed could provide ample storage, or, set on its side, a spacious 2-floor habitat module. The adaptor skirt covered the SIVB engine and mated the SIVB to the Saturn 2nd stage. This could be saved also.

Yes, to deliver this stage the rest of the way to a soft landing on the Moon requires more fuel, but at least the oxygen required could be brought up from the lunar surface. Delivered, this adds large fuel tanks which could be put to welcome use in the moonbase, plus an engine, cannibalizable wiring and other components. Remember, we already paid the freight to get it almost all the way!

Those with shortsighted vision would not want to bother, but if you are a prospective lunar pioneer, not to take advantage of such a golden opportunity would be unforgivable, and as lunar frontier history may someday judge, forever listed as an act of unthinking treason against the future Lunar Republic.

We are not suggesting that the Lunar Module ride to the surface atop this 3rd stage, *though if we decided to do that,* the weight savings involved in not needing to equip the Lunar module with its own separate descent stage engines and tanks, might go a good ways toward paying for the extra fuel.

The equivalent of the Apollo Command Module needed to return crew to Earth orbit or to Earth directly, could be dropped off en route, breaking into lunar orbit, while the 3rd stage with lunar module and minimalized ascent stage continued directly to the lunar surface. It's a different lunar architecture but the potential payoff in "total payload delivered" is too great not to pursue. As we work out the design and tradeoff particulars, a show-stopper problem may emerge, but with the right attitude, we can bet that a doable workaround will be found.

In the scenario above, even the farings that protected the lunar lander on its trip up through Earth's atmosphere, could make the trip all the way. They would surely be useful for one thing or another.

A Proper Guiding "Philosophy" is essential

We must always keep in mind that *maximum total payload mass delivered is the Holy Grail.* That implies, of course, that we have predesigned every "hitchhiking" component to be able to serve new uses and functions on the Moon, or have made that component of a material that we cannot yet produce on the Moon, or may never be able to produce, such as copper, brass, zinc, lead, and reshapable thermoplastics, to name a few.

What about parts for which we can foresee no reuse or reapplication potential? We can think of two approaches right off the bat. Make them of materials needed on the Moon. Store them up until someone does have use for them. At the very least, they can be used in frontier sculptures, symbolizing the effort it took to establish the frontier! Art is one very important way we begin to accept our new surroundings as "home."

Face it, we will not have bottomless financial reserves, we will need to be spartan. Why not borrow the operating principal used by the poor who need to use *all of everything that comes there way,* in this example, a slaughtered pig -- "use everything except the squeal." To put it in more common terms, we need to maximize and ramp up our "resourcefulness."

This is not "Apollo II"

We need to remember that in the Apollo program, the idea was not to establish a permanent base, but to conduct a series of science "picnics" at scattered surface sites. In that light, minimizing landed mass on the Moon was the proper design goal. Now, as we pick one site and try to build it up to the point where it becomes a truly functional complex serving a wide variety of operations on a long term basis, everything changes. We will want to deliver as much, not as little, as possible.

By including as second class payload, not just crew, cargo, and initial cabin, but the entire landing craft and perhaps the entire assembly that left Earth orbit

bound for the Moon, we demolish the Old "mass fraction limits" on deliverable payload. And we demolish those limits at relatively little extra expense. The payoff of adopting this design philosophy is that a given stage of moonbase buildout can be reached in fewer trips from Earth, or conversely, with the same number of trips from Earth, we can reach a much larger, more complex and elaborate lunar outpost buildout.

This is important for an operation that needs to maintain public and political support to continue. The more we achieve with the lowest cost, the faster our presence on the Moon grows first to a fully functional science and exploration outpost, then towards one involving a growing number of civilians involved in industrial operations aimed at tackling Earth's energy and environmental problems, the more surely it will survive changes in political administrations, and congressional whims.

A parallel with the Opening Act of the Universe

The only safe lunar outpost expansion philosophy is an "inflationary" one, growing and evolving very fast, *not very slow*. Until we reach a stage where our presence on the Moon can survive periods of interrupted support from Earth, everything is tentative, subject to a change in the winds that could mean a second retreat from Luna.

Such a swift buildout approach will, when all is counted up, be significantly less costly than a go slow, pay as you go approach. Time is the most costly expense a of all. We should know this from the Shuttle program. Initial cost per launch figures where based on sixty launches per year, one every six days. Now we are lucky to do four or five. But the expense of the standing army of people needed for turnaround, as well as of management, never goes down in proportion to mission rate.

Further, with each delay, inflationary pressures come into place. To get our money's worth we not only have to reuse everything sent *toward* the Moon *on* the Moon, but we need to buildout our lunar facilities and operations with all due speed.

The "Medium is the Message"

We noted last month that extending Marshal McLuhan's dictum that the Medium is the Message to rocket transportation and delivery architectures, the rocket itself can be part of the payload, if properly designed, in all its parts, for useful applications at the delivery site.

Meanwhile, the original second stage, which delivers the moon-bound stack to Earth orbit, should itself be predesigned so that all its components can serve some useful function in Earth orbit, building up the transportation hub with refueling, assembly, and maintenance operations functions. We've already paid the freight to deliver its fuel-expended dry mass to LEO. If we do not leave it there and find someway to use it to ramp up orbital operations, we are just tossing money away. Here too, we can treat the Mass Fraction limits.

It begins to look as if the Mass fraction rule was a product of neanderthal thinking. We got to where we are by taking advantage of every opportunity, not by mind-lessly throwing opportunities away, because in our narrow horseblindered professions we can't see the possibilities!

Next Month, Part 3 - Bootstrapping through LEO and LLO with early lunar products. <MMM>

"Towards an Earth-Moon Economy Developing Off-Planet Resources"
Moon Miners' Manifesto
& The Moon Society Journal www.MoonMinersManifesto.com

The MMM Classics

http://www.moonssociety.org/publications/mmm_classics/

Articles from issues #1-210 have been reprinted in pdf file volumes of **Moon Miners' Manifesto Classics**, one per year, ten issues each.

The MMM Classics volumes are **freely downloadable from this directory:**

www.moonsociety.org/publications/mmm_classics/

Articles from issues #210 forward will be included in future volumes of MMM Classics which we hope to publish annually, maintaining a lag of 3 plus years behind the current issue, to preserve incentives for membership.

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