

Moon Miners’ Manifesto

& The Moon Society Journal

www.MoonMinersManifesto.com

MMM Classics

Year 22: MMMs 211-220

DEC 2007 – NOV 2008

Illustrations Key:

Five of the most interesting articles this publication year, (see the five illustrations at right) were on:

- The Concept of “World” from flat to round to the realm of human activity “wherever”
- “Assuring Mental Health among Future Lunar Pioneers”
- “Railroading on Mars”
- “Bursting Apollo’s Envelope” and
- The Moon’s Remarkable “Alpine Valley.”

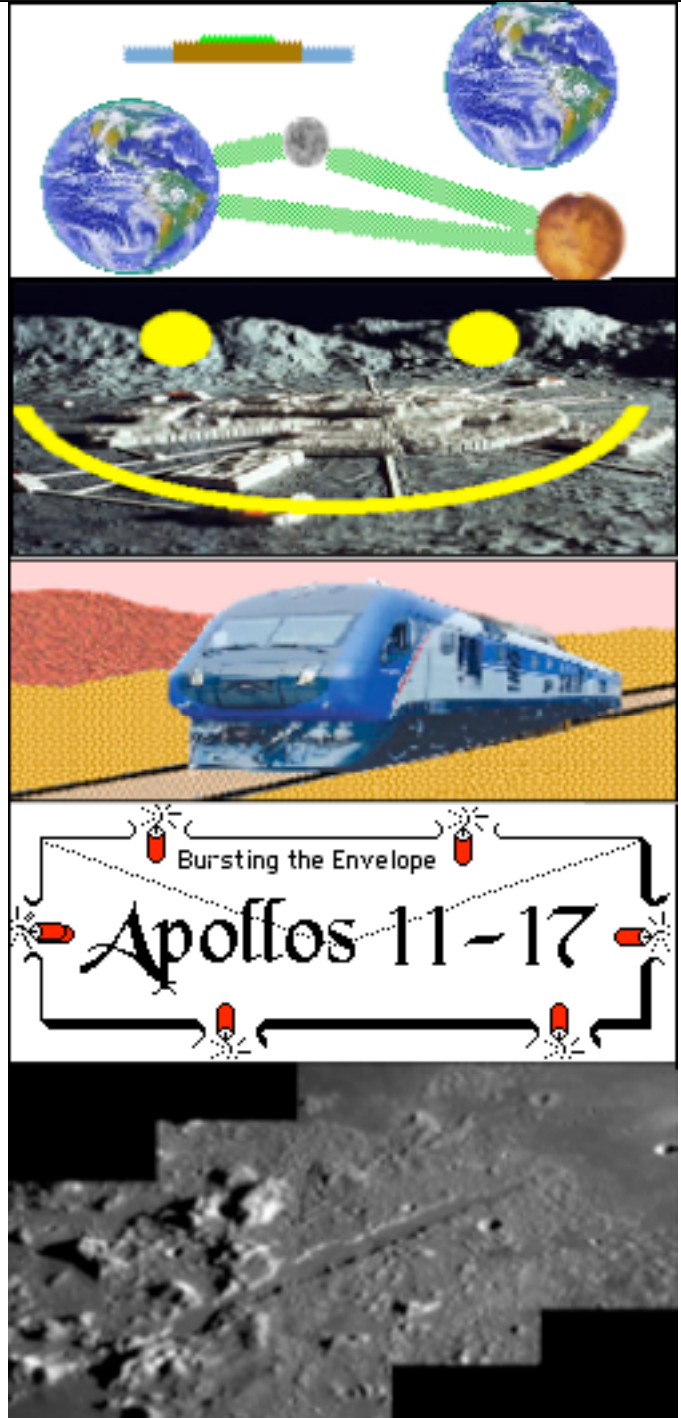
Other articles of note include:

- “Thinking Outside the Mass Fraction Box” (we have handicapped our options for space transportation because of slavery to an unexamined assumption dating from Penemunde!
- MMM’s “Platform for Mars 2.0” and other articles on Mars in our annual “March is for Mars” theme issue
- Aspects of an Early Lunar Community
- Taking the Green Movement to the Moon (several articles);
- Hewn Basalt Products
- Saddlebag Shielding for Vertical Habitats
- Shadow Pioneers (Earthbound teleoperators)
- Distance limits to tele-conversation
- Does it really take more fuel to land on the Moon than on Mars as Robert Zubrin claims?
- A major article series by Dave Dietzler focuses on “LUNAR ENTERPRISE & OPPORTUNITY Parts 1-4
- The “Mother Earth & Father Sky” article touched again on the green themes.
- Gordon Haverland contributed a critique on the options for “Engineering on the Moon and Beyond with local materials.
- The tragedy of discarding of External Tanks, was touched on again: something MMM has opposed from the very beginning.

In Addition

There were a number of Book Reviews

We do not preplan the article spread in any publication year. Some topics are revisited more often than others. It all depends on the inspirations of the contributing authors. *Thanks, and Enjoy!*



[MMM 21st Anniversary Essay]

AS THE WORLD EXPANDS

The Epic of Human Expansion Continues

by Peter Kokh

I have often heard the complaining question, “why can’t we just stick to our homeworld,” to which I am quick to reply, “It’s too late for that. Our homeworld was Africa and we expanded beyond that nearly a hundred thousand years ago. Expanding our “world” defines that Epic. Who are we to be the generation that says “halt?”

This sort of impatience with endless progress” is hardly new. In the aftermath of World War I, leading up to World War II, the great pioneering British science fiction film “Things to Come” (Raymond Massey lead star), a film rendering of H.G. Wells’ “The Shape of Things to Come” (1933) dealt with this impatience with endless change.

The irritating fact is that the pace of change, of progress, of expansion is ever accelerating, and adjusting to that is hard for many individuals.

It is more than four centuries since the “world” as known to Europeans grew by the “discoveries” of the Americas. In actuality the epic of expansion has always proceeded quite a bit in advance of popular awareness of it. Humans advanced “out of Africa” into Eurasia yet few people either in Africa or Eurasia may have been aware of the new larger combined “world.”

What is a/the “World?”

Perhaps most people will understand “world” to mean “the planet Earth.” We speak of other planets as other worlds. That *is* the contemporary understanding. But to get at the real meaning of “world” we must look at the concept phenomenologically. I would define world as “a continuum of horizons,

- from no point within which, the whole is visible.”

That fits the “world” of our most ancient ancestors, as well as of our own era. Interestingly enough, it does not fit O’Neillian space settlements as I have pointed out in my 1996 paper, “Reinventing Space Oases.”

www.lunar-reclamation.org/papers/reinv_so.htm

Originally, the “World” of humanity was Africa

While the exact figures may change as we learn more, the DNA evidence from mitochondria which are only passed on through mothers (as mitochondria are only found in the egg) is that all extant (living survivors) humans are descended from one female in Africa about 140,000 years ago. This does not say that there were no other proto-humans at that time, but only that, if there were, none of their descendants have survived. Nor does it say that this female mated with only one male.

The evidence goes on to conclude that all extant branches of humanity excluding modern day Africans, are descended from one female who made the crossing into Asia, not via Egypt, as previously thought, but across the straights of Aden at the bottom of the Red Sea, straights which these days are 20 miles across. At that time, 80,000 years ago, the “world” of humans began to expand considerably until all parts of Eurasia were

inhabited, and migration into Australia and the Pacific Islands and even into the Americas had begun.

The World is Flat

But until we began to reach the “East” by going “West” the common perception was that the world was round. True, ancient Greeks had realized that the world was round from two lines of evidence:

- The curvature of the Earth’s shadow on the Moon during lunar eclipses
- The change in apparent latitude of key stars as one traveled from Greece to Egypt
- But to the average person the world remained flat.

The World becomes Round

In the 16th century as cross-Atlantic and around-the-world exploration became common, the reality of a round world sank in. Ever since, the spherical nature of the world has become ever more assertive as we have developed one new method of swift communication after another. When the first telegraph and telephone lines were laid across the bottom of the Atlantic connecting North America with Europe in 1866, the effect on public world consciousness was considerable.

Not quite a century later, Telstar 1, launched July 10, 1962, brought live television pictures originating in the US to France that same day. Ever since we have enjoyed live newscasts and sportcasts from around the world. We not only shared one round world, we were now actively interconnected over very short time intervals.

And now we have the World Wide Web, the Internet. The World has grown a brain of sorts. The “noosphere” predicted by French Jesuit philosopher Teilhard de Chardin (died 1955) has become reality.

From Africans to Terrestrials to Solarians

During the past century or more, we have equated “World” with “Earth” but that perception, that identification, as logical as it now seems, is going to change. Think of it. The “world” can also be described, without prejudice to the definition I offered above, as “a continuum of horizons,

- from no point of which, the whole is visible,
- but between all points of which,
- travel and communication may become routine.”

Communications with the Moon involve a delay of under 3 seconds, between Earth-Moon and Mars, between 6 and 40 minutes. Compare that with the delay in communications in the 16th Century -- as much as months -- when everyone accepted that all parts of Earth made up one world.

That “World” defines a set of routinely inter-communicating living spaces, is more apt a definition than any which restricts “World” to any one celestial body. Now I put “routinely” into the definition to exclude possible extra-solar civilizations many light years apart, where sporadic one-way communications taking generations is possible.

“Our” world will in time include settlements on the Moon, expeditions in transit within the solar system, and outposts on Mars, and even beyond. You can get an answer to a question sent to an outpost on Pluto within a day, a lot faster than Queen Isabella and King Ferdinand heard back from Columbus. **The world, to future generations, will not mean “Earth”. It will mean the inhabited part of the Solar System. Get used to it!**

From just one Earth continent, to all planet Earth, to everything in Earth's orbit around the Sun, to everything reachable within Earth's Solar System, the Epic of Human Expansion continues and is inevitable. If it were to stop because of deliberately cherished ignorance or through a failure of will, mankind will have betrayed its mission. "Go and expand into all the world." "All the world" is on the verge of becoming "all the Solar System."

"World" is as inclusive as technology allows

Our world to the extent that it means "everything within our reach" keeps expanding as our technology keeps expanding. Our Epic has involved one great leap after another. The time has come for the next. Not to take this leap means to turn our back on the potential within us, to say "No" to God or to whatever forces you prefer to believe have resulted in our existence.

Copernicus opened up our eyes to a universe populated by other worlds (this time, used in the sense of planets, or better, as bodies which could conceivably be or become theaters of human or intelligent activity. But it is only the age of the rocket which has allowed human travel to "continents" across the ocean of space, that has brought us to this point. Tomorrow, "world" in the sense of the evening news, will routinely include venues beyond the "original" seven continents. With modern communications it makes no difference if we are reporting human news stories from the Moon, from Antarctica, from any other terrestrial "Timbuktu" or from elsewhere in our own local community. The boundaries of "the human theater" commonly called "the world" are expanding outward.

In the era when humans lived only in Africa, the "world" included but one continent. Even as humans expanded through Eurasia, we were still confined to one big interconnected supercontinent. That the "world" would leap ocean barriers to the Americas, Australia, and the Pacific Islands was the first giant leap, the point at which we became truly intercontinental, perhaps as much as 40,000 years ago. The intervening seas did not matter because we could travel and communicate across them, at first with difficulty, but then routinely.

In the age of aviation, it has become irrelevant if there is land or sea along our route. Can "short" stretches of Earth-hugging "space" be any different? The spacial "straight" separating Earth from Moon is no longer a barrier to either routine travel or routine communication. The Earth-Moon system will become one "world."

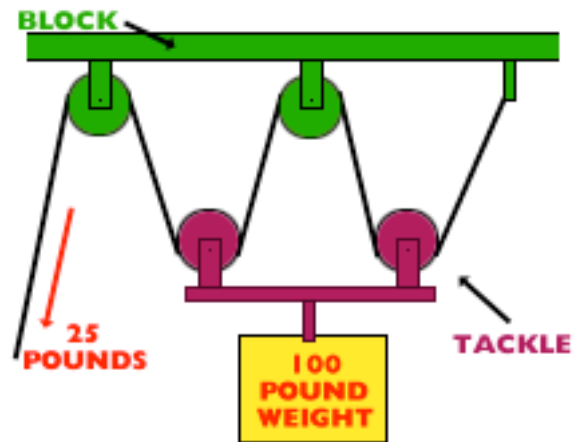
Both travel and communication will take longer to other points in the solar system, but are of little consequence in comparison to the difficulty of travel and communication in the post-Columbus, post-Magellan world. To continue to think of "world" as confined to Earth, is to think in tribal terms.

This Epic leap is not yet a solidified reality. It will become so as early science outposts on the Moon are followed by civilian industrial settlements engaged in making a living by selling goods and services of use to those remaining on Earth and endeavoring to manage their growing energy and environmental issues.

In a very real sense, the global decision to expand our present global economy to include the Moon will be the most critical test humanity has ever faced. At no time in the past have we faced such an opportunity and temptation to say, "No, enough already!" At no other time have we had the chance to betray our self and our "mission," the ultimate test of human free will, to become or not "Solarians."

<MMM>

THINKING OUTSIDE THE MASS FRACTION BOX: 3



The Block & Tackle Pulley as an Analogy of the Power of Leveraging Concurrent Space Developments to deliver *much more* to the Moon

By Peter Kokh

"in Earth orbit you are halfway to anywhere"

– Robert A. Heinlein

The "effective" cost of goods delivered to the lunar surface depends on the amount, or lack of infrastructure along the way.

Archimedes invention of the pulley more than 2200 years ago is one of the most important mechanical contributions to early civilization. By realizing a predictable mechanical advantage, the "energy cost" of moving an object from one plane, say Earth's surface, to another, say the Moon's surface is significantly reduced. The block and Tackle pulley multiplies the advantage.

What does this have to do with space transportation in general, and with the cost of delivery of goods from Earth to the Moon in particular? We certainly are not talking about setting up a physical block and tackle system in space! Rather we want to apply the analogy above in a way that illuminates the best way for us to proceed.

In short, transporting things to the Moon without any intervening infrastructure, i.e. not cashing in any infrastructure discounts or advantages, is going to remain very expensive. The "Moon Direct" plan, if we can call it that, is the "horse blinder" choice. "We are directed to put an outpost on the Moon, not to establish infrastructure along the route." What looks like dedication will someday reveal itself to be an outright waste of resources and opportunities. Future Lunans may even view it as criminal.

In previous parts of this article, we have noted that anything taken to orbit that might be useful in setting up shop on the Moon, but left to fiery destruction as its orbit decays, could be taken to the Moon at much less expense from LEO than from Earth's surface – if Heinlein is right, for about half the cost. And that includes a lot of material, whether usable in its current form or not. The deliberate "wasting" of the External Tank is but the most obvious and long standing forfeit of

opportunity. We fully understand all the disadvantages and obstacles to reusing the ET. But they are insignificant in comparison to what could have been gained by committing to the modest expense of parking them in a higher very long duration orbit until the opportunity to use them in LEO or take them to the Moon arose. As a Society, we have become addicted to favoring short-term advantages over long-term goals, and such a habit, if we don't fight the addiction, could have us following the Romans into oblivion. Again, I understand the excuses. But excuses are just what they are.

The same holds true of anything else delivered to LEO and GEO, which when no longer useful there, could be delivered to the Moon at "half the cost." LEO and GEO are pulleys in any future fully developed lunar transportation system. So is the Earth-Moon L1 Lagrange point and other lunar orbits. Anything delivered that far that could be used, reused, restructured, or cannibalized on the Moon will be far cheaper to deliver than an equivalent item all the way from Earth.

The Lunar side of the Block & Tackle

I remember Gordon Woodcock's paper which sought to prove that lunar oxygen used to refuel Moon-bound cargo ships, could only reduce the cost of shipping to the Moon, but not make it profitable. Duh! What's wrong with reducing costs? Lunar oxygen, which is abundant beyond exhaustion, can be shipped to L! and to LEO with every returning vehicle, to partially refuel each next Moon-bound craft. LOX is thus another pulley in the system. As to LH₂, which is *not* in large supply on the Moon, we oppose shipping that off-Moon as fuel, or even for using on the Moon as fuel, except for fuel cells in which hydrogen can be recovered. Any shipment of hydrogen off the Moon limits the size to which lunar settlements and biospheres can grow. In that perspective, such shipment and usage becomes treasonable against the Lunar Frontier.

Lunar Exports

Many people point out that the Moon has nothing of value "on Earth" except perhaps Helium-3, and maybe platinum (I am very dubious of this latter idea.) What these people are failing to understand is that the logical export partner of the Moon, is not Earth, but LEO. *Anything that can be made on the Moon to fit service needs in LEO can be shipped to LEO at a 20:1 fuel cost advantage over shipment of equivalent goods up from Earth's surface.* Of course, that statement does not factor in the need to amortize the costs of developing lunar industries needed to export such items. That does not change the argument, however.

Items made of concrete, cast basalt, glass, alloys of steel, aluminum, magnesium, and titanium are candidates. Yes, there will be some specialty materials that lunar industries won't soon be able to match. But in designing LEO installations - space stations, laboratories, factories, tourist facilities, whatever, if the design team tweaks the design to use lunar products, the cost savings will be considerable. Even dehydrated food, over 50% lunar oxygen by weight, can be shipped more cheaply to LEO than from Earth! The point is, that all these export products will help defray the cost of shipping things in LEO the rest of the way to the Moon. Another Pulley!

Not to forget GEO

GEO -- Geostationary Earth Orbit -- is long overdue for wholesale restructuring of the way the limited and invaluable slots along this orbit are assigned and utilized. With large platforms supplying power and station keeping, serviced by robotic tugs, many communications and other GEO satellites can share the same orbital slot, taken to the platform by the tug, and "plugged in." GEO is almost saturated in our present "hunter-gatherer" level of allotting space. How will products from the Moon help?

We already understand that lunar materials can bring down the cost of solar power satellites and relays in GEO by substantial proportions. [See last month's MMM proposal for a World Wide Orbital Grid.] These same materials can help build new and larger platforms for communications and other uses. And the tugs needed will be of use as well in LEO in maximizing reuse and salvage of items in orbit, including gathering them for transshipment to the Moon. GEO platforms, power systems and tugs -- another Pulley"

"Mechanical" Cost Advantages

Any estimate of what it will cost to open the Lunar Frontier, that neglects the opportunities to ship to the Moon anything shipped to LEO, GEO, or other points in between and no longer needed at those points, or which neglects to credit exports from the Moon to LEO, GEO, or other points between will necessarily be fantastically outlandish.

At the same time, we are not saying that opening the Lunar Frontier will quite pay for itself in the near future. That said, we are confident it will do so much more quickly than most authorities now estimate. Those less optimistic predictions are a natural, given the human tendency to be too optimistic in predicting the near-term future and far too pessimistic in predicting the long-term future.

I was asked recently to outline "The Ten Steps Needed to Create an Earth-Moon Economy." I dislike pre-set outlines. Whether it is five steps or fifty is uncertain. But this set of articles on "Thinking outside the Mass-Fraction Box" are my first installment towards an answer to that request. In other words, *we are not going to succeed in setting up an Earth-Moon economy without paying attention to "the pulley points" along the way.*

LEO & GEO can only be fully developed using the significant cost advantage of Lunar materials and exports.

The Moon cannot be fully developed without access to materials and items shipped to LEO which when they are of no further use there, are then transhipped to the Moon.

The first Step: a refueling station in LEO

At the 2007 International Space Development Conference in Dallas over the Memorial Day Weekend, Dallas Bienhoff of Boeing gave a convincing presentation that simply by refueling Moon-bound craft in LEO, we could deliver 60% more goods for the money. Please view the three video segments produced by the Moon Society in which Bienhoff explains his thesis.

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Bienhoff is correct in saying that NASA has an obligation to identify the least expensive way back to the Moon. However, that constraint imposed by Congress, is shortsighted, in words we all know, “*pennywise and pound foolish.*” The current Spartan approach can only be defended if setting up a lunar outpost is a goal in its own, without considering further use of that outpost, or further lunar developments.

Many years ago, I wrote in an In Focus editorial which I can't locate at the moment, that the space enthusiast community has all too often attempted to sell the ladder of our dream *one rung at a time*. When we do that, the rung in question gets designed as a be-all and end-all in itself, *not as a rung leading to the next rung, not as part of the ladder*. Thus we have only ourselves to blame for the Space Station becoming a black hole for funding, leading nowhere. In the selling of the Station, it became not a depot to outer space as conceived of by Wernher von Braun, but a downward looking Earth-research laboratory, the pride of “yo-yo space.” We were afraid that if we talked about our real dream, no one would listen. The result of this space enthusiast consensus strategy of the early eighties is 20-some years since of going nowhere.

If we promote the NASA permanent, but not permanently occupied, science outpost as a goal in itself, that's what it will become. Because we can't allow ourselves as a nation to look further down the road, we will continue to make stupid shortsighted decisions which will only bring further delays to opening the Moon.

Anything that is worth doing is worth doing right. We have to rethink the NASA moonbase as a *rung in a ladder*, that means flushing LAT-2 down the LATrine. It's a quite brilliant design intended to lead to nowhere.

Ten Steps to an Earth-Moon Economy?

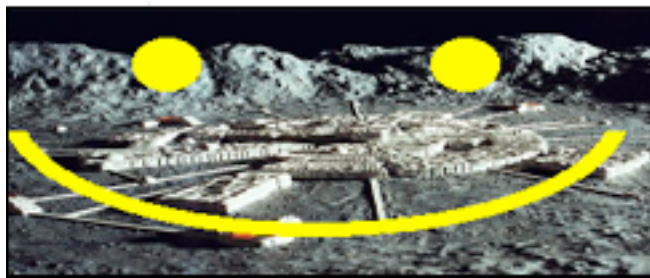
It includes building up a block-&-tackle-reminiscent set of cost savings enhancers in LEO, GEO, L1, and on the Moon itself. And it includes dumping LAT-2 constraints. NASA has rightfully canceled further biological life support system research as not of use for its current concept of the lunar outpost. Can there be any more eloquent clue that the agency is off track, way off on a tangent?

NASA itself admits the potential for using lunar resources, but has chosen for this Congressional assignment to constrict its vision to what is pertinent for the mission so defined. In its dedication, NASA has unwittingly chosen to become part of the problem. Yet the agency has enormous expertise and problem solving resources. It needs a change in direction that unleashes those talents. Perhaps the next administration will see to that. In the Apollo program, NASA was at its prime. Under present leadership, the agency is playing a caricature role, expertly. But this is the price we pay for a space program that continues to be a political football.

We, those of us in the bleachers, disparaged by NASA and the government alike, have to be vigilant for ways to make an end run around what is happening. The LEO and GEO and even Lunar export options we have mentioned will be the work of private enterprise. That's our point of entry. Optimism has to be earned. <MMM>

MMM #212 – FEB 2008

Assuring Mental Health Among Future Lunar Frontier Pioneers



Space 1999 Moonbase Alpha sporting a “happy face”

By Peter Kokh

Introduction

A central focus of MM “Manifesto” from the start has been to show how, using lunar resources, pioneers can make themselves “at home” on the Moon. This will include psychological, physiological, social and cultural adjustment to living in the Lunar environment, perceived by us outsiders as “alien.”

It is crucial that pioneers, people who may or may not have originally come “for a tour of duty” but have decided to stay, must get to that stage where they are “at home” on the Moon, comfortable with it, feeling secure. Staffing a settlement with recruits for limited tours of duty will not promote this transformation into a population of “Lunans” unless there is an aggressive strategy of perks that keep personnel happy, while minimizing homesickness and encouraging an increasing comfort level with this new setting. Without such **perks**, recruits will be discouraged from “reupping” or reenlisting or “going permanent.”

Once we are building new habitat and activity modules from **made-on-Luna building materials**, we can get well beyond the “sardine-can” era of early outposts. Real elbow room and ample private space will be essential. We need to emphasize “contact”, visual, and activity wise with the Moon: windows, sunshine access, and **abundant interior vegetation** to keep the air fresh and sweet.

We will need to develop a varied and interesting developing **cuisine** using plants, herbs, and spices grown on location. Regolith-derived art media will allow us to personalize interior spaces with frontier made accessories of basalt, ceramic, glass, lunar cement, and locally made alloys.

We need to invent and develop **one sixth-G sports** as well as **dance forms**. We need to be able to enjoy uniquely lunan performances as they will help bond us to the lunar setting. **Recreation inside, “middoors”, and “out-vac”** will allow us to be fully human in any lunar setting.

We need to establish multiple outposts, multiple settings -- getaway places with climate variety, flora and fauna variety, different architectural styles, differing cuisines, etc. We all need to “getaway” once in a while, and we have to enable that form of relief on the Moon itself. “settlement a world doth not make!”

It is not enough to humanize our interior living spaces. We need to adopt the surrounding raw lunar surface outside our habitats and integrate it into our living space. If we do not, we will continue to feel that we are in an alien environment. In short, we need to feel "at home" on the surface as well as indoors.

We need to be comfortable with the Moon's rhythms, the slow pace of the dayspan-nightspace cycle. Our productive activities will have to get in step with that pace as available energy will wax and wane accordingly. Even if we have a back-up nuke, we will still have more available energy during dayspan when solar energy is also available. This rhythm will impose a fortnightly change of pace, something we bet pioneers will come to cherish.

We need to find ways to counter the "black sky blues." Out on the lunar surface, we will develop ever more enjoyable substitutes for outdoor hobbies and activities that we had to leave behind on Earth.

In other words, we need to find, create, or develop substitutes for everything we enjoyed on Earth that cannot be imported "as is" from Earth, simply because the Moon is such a drastically different environment. If we fail to do so, life on the Moon will give rise to many kinds of psychological disorders. We must strip the Moon of its alienness by doing what we can to meet her halfway. I firmly believe we can rise to the occasion!

Introducing "perks" in the first outposts

The most critical moonbase system to succeed is the human one. Our goal of breaking out of the outpost trap towards settlement, means finding ways to encourage personnel to willingly re-up, stay for "another tour" without limit, so long as health of the individual and of the crew at large is not an issue. These measures will

1. increase morale and improve performance
2. promote willingness to re-up so as to give the weight allowance for his not-needed replacement to valuable imports of materials and equipment, especially tools and equipment to fabricate and experiment
3. create a plan for outpost expansion of modules, the facilities they house and activities they enable

We must provide a full range of human activities

- getaway "change of scenery" spaces and out-places both within the outpost and with outlying stations in easy reach.
- customizing options for personal quarters
- menu diversity and variety, including fresh salad stuffs and vegetables on occasion
- schedule breaks (take advantage of the dayspan/nightspace cycle for regular changes of pace such as alternating types of work and recreation)
- allow fraternization between crew members, without harassment. An outpost should not be a monastery.
- promote expression of artistic and craftsman instincts using local materials and media. We will remain forever "strangers in a strange land" to the extent we confine ourselves to things made on Earth.
- Experiment with lunar sports and other recreational activities. Lunar-unique sports and performing arts – are things that make crew begin to "feel at home".
- out-vac sport & recreation on the surface, learning to do so safely, one step at a time.

- an indulgent spa and an exercise gym
- telecasts to Earth of everything unique and special
- "while you are here" opportunities for excursion exploration and "tourist" experiences and memories

All this both presupposes and prepares for an orderly expansion beyond the original core-function and space limits of the original outpost. It's what we need to do to "breakout of the Outpost Trap."

----- Point by Point Elaboration -----

Made-on-Luna Habitat & Activity Expansion Modules

Lunar concrete, glass-glass composites and iron, aluminum, magnesium, and titanium alloys are materials science technologies that need to be pre-developed now using lunar simulant feedstocks. We cannot afford to expand by bringing these heavyweight structures from Earth. Inflatables may be a stopgap way of providing expansion space early on, but are still too expensive for building real settlements. We need to develop a modular language that will lend itself to a great variety of layouts. That language should be open-ended. The very awareness that one has begun to "live of the lunar land" in this major way will reduce our sense of alienation, and increase our sense of security.

Towards a modular biospherics

Centralized biological life support systems (BLSS) such as Biosphere II involve a lot of effort that quickly becomes useless as it precludes growth. These made-on-Luna modules should each incorporate a significant biospheric element, pretreating toilet wastes and using vegetation to refresh the air. With this design constraint, the growth of the pressurized physical complex will not outpace the growth of the biospheric life support system, and new modules can incorporate improved systems, so that the total biosphere becomes ever larger and more collapse-resistant. With such a system, short term crew as well as the long-term pioneers that follow will grow ever more confident that their presence on the Moon is well-founded and hearty.

Beyond a minimum "balanced nutrition" diet

There have been many studies of how we could provide balanced nutrition with a minimum number of crops. That's certainly a useless dead-end avenue of investigation. Nothing is more essential to good morale than good food. And by good food, we mean tasty food and a goodly variety of it. If we need to trim the list, we should concentrate first on those foodstuffs that can be served and prepared in the greatest variety of ways -- potatoes being near the top in that regard. We also need to grow herbs, spices, and salad stuffs that can be eaten fresh as well as lending themselves to a wide variety of cooked dishes. We might have to settle for a closet-sized growth chamber for starters, but surely, no-one is going to leave Earth in their rear view mirror something that approximates soylent green or algae mush. A starter list of choices can always be complemented by privately grown specialty items, even in a small outpost. As the settlement grows, this will become a great opportunity for "cottage industry" – think jams, condiments, etc.

Keeping physically fit

It never ceases to amaze me how many pro-space people equate 1/6th-G with zero-G. The

difference, at least mathematically, is infinite. Muscle tone will decay of course, but then level off at a plateau appreciably higher than is the case for those spending many months in Earth-orbit or free space.

At first, "keeping fit" will mean keeping in shape to return to Earth ready to resume normal activities when one gets back. But as temporary crews slowly transition to a population that includes a significant percentage of permanent pioneers, "keeping fit" will mean what it should, able to work and play with relative ease in what will have become one's home environment.

Terrestrial sports transplanted to the Moon will be just absurd caricatures of the sports we now enjoy. We need to invent sports forms that are interesting to watch and fun to play in an environment where gravity and traction are greatly reduced, while momentum and impact force remain the same. We could start now, with a computer program based on those parameters, applied to both sports and choreography. Future Lunans will miss terrestrial sports and dance less, the sooner they can enjoy sports and dance designed for the lunar environment. The morale boost will apply to players and performers as well as to spectators. Lunar sports, lunar acrobatics, lunar dance and ice-skating forms may gain an audience back on Earth via live or canned telecasts and the Internet.

But we do need to provide special gyms and devices whereby one who wants to maintain an Earth-fit state, to do so. It is one thing to appreciate how much one has adapted to the Moon, another to feel trapped on the Moon because one has lost his/her Earth muscles. The simplest way to retain one's original muscle tone is by isometric exercises that pit muscle against muscle rather than muscle against gravity. exercise in a banked floor rotating gym at variable rates would be an advanced way to preserve one's "Earth legs."

Settlement climate, flora and fauna, even wildlife are wide open choices

As we are talking about contained climates and ecosystems, we can control the settlement climate and seasons. Not everyone enjoys the same climate. While many snowbelters yearn to relocate further south, this writer cannot tolerate heat with humidity, and would rather go further north. Because settlements will have a great measure of control over these things, even apart from cultural and architectural differences, the Moon need not be a world where "once you've seen one lunar settlement, you'll have seen them all." Not only will variety in these areas work to increase the typical length of an Earth tourist visit by lengthening the itinerary, it will give future lunans more places to get away to for a welcome change of scenery.

It is not enough to be "at home" inside one's homestead and settlement

If this is all one accomplishes, a residual uncomfortable with the barren, hostile moonscapes outside -- "out-vac" -- may remain. Some will feel imprisoned, and even dread venturing abroad. But there are ways, analogous to how we are learning to do this here on Earth, to both "bring the outside indoors" and "take the indoors outside." For example we could create indoor garden spaces in Zen fashion, using raw regolith (sifted of its ultra fine powder fraction) and lunar stones and boulders, in a cast basalt pan.



Art accessories can be made of carved basalt or cast basalt, lunar raw blackish glass, etc. We could do something similar outside airlocks using stone or cast basalt "patio" furniture and sculptures. Both approaches would help create a visual transition between exterior surface and interior decor. One could even create a glass enclosed water feature outside. This will be easier in shaded places with greatly reduced thermal exposure.

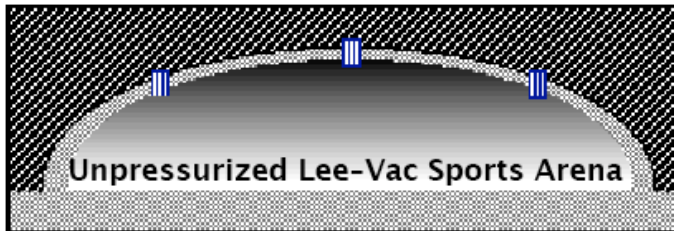
Inside, "middoors", "lee-vac", "out-vac"

Here on Earth, we commonly think of just two spaces, indoors and outdoors. However, we are all familiar with a transition space - the walkway commons of enclosed shopping malls. In this example, "indoors" would refer to the interior of the various shops and stores. In a settlement with modular residences, offices, schools etc., interconnected by pressurized walkways, vehicular conduits, and pressurized plazas, courtyards, and parks, these interconnecting passages and spacious nodes/hubs form a sort of "middoors" environment.

The middoors could be allowed to cycle between cooler and warmer periods in "moderated" synch with the outside or "out-vac" thermal cycles of the exposed lunar surface. While individual homesteads, offices, and other activity spaces could maintain a constant climate, the middoors would moderate the changes occurring on the surface, varying perhaps twenty degrees Fahrenheit, 36 degrees Celsius above and below "room temperature. That is one of many options.

A third kind of environment, which in turn moderates the thermal and radiation extremes of the fully exposed surface is "lee-vac" (leeward of the cosmic weather.) An example is a sheltered but unpressurized structure, canopy, or ramada within which one is protected from the cosmic elements of radiation and micrometeorite rain, as well as from the full heat of dayspan noon on the exposed lunar surface. Lee-vac spaces would be ideal for warehousing items and supplies that are accessed frequently. In such an environment lighter weight pressure suits would be sufficient, allowing much greater freedom of movement, greatly increasing the time one could work without fatigue.

We can see such a sheltered, but unpressurized sports complex. Sports designed especially for this environment would be different from those designed for pressurized play environments. pressurized spectator stands could line the interior side walls of such sheltered and shielded fields could have large windows, protected from meteorite impact. As these sports would be quite distinct from those played in fully pressurized environments, creating such sport environments would increase the variety of sports fare, improving pioneer satisfaction with their adopted home world.



Finally, we can see development of various kinds of sports and sporting activities for the naked exposed lunar surface itself – the “out-vac.” This great variety of sports fare crossing the boundaries of raw exposed lunar surface and settlement interiors, would help psychologically integrate the lunar surface into the overall pioneer lebensraum – living space. The result would be an increase in the average Lunan pioneer comfort zone, a mitigation of a “trapped indoors” feeling, and a slow dissipation of the initial tendency to feel like a “stranger in a strange land.”

For young people, regular school outings onto the surface would help. And undoubtedly tourist surface excursions will become the specialty of emergent enterprises, serving both visitors from Old Earth and pioneers of the New Moon. Until this familiarity and comfort level with the raw host environment develops, we can expect some incidence of exophobia to develop, along with a feeling of being trapped.

Adaptations like this are nothing new to humans. Take a person out of his/her native tropics and drop him/her along the arctic coasts, and he/she might soon perish. Eskimos, Inuit, Samoyeds are at home here. They learned to be at home. An initially life-threatening environment is, for them, no longer to be feared. Simply put, they have learned how to cope with the evident extremes and dangers “as if by second nature.” When future pioneers have learned how to cope with conditions once perceived as hostile to life, and those coping measures have become “second nature,” they will have become “at home.” The Moon, for them, will have ceased to become a hostile, inimical place. It will have become home. Such a transition will be essential for their mental and psychological health. Those who cannot make or resist making the transition will become failed settlers, and will either return to Earth or become a burden to those who have successfully transitioned.

The “Black Sky Blues”

One of the hardest things to get used to in the lunar environment will be the black skies, at high dayspan noon as well as at mid-nightspan. And they are black indeed. When the sun is up, the glare off the moondust forces eye pupils to adjust to the point where one cannot see the stars. We have evolved in the brilliant blue day lit skies of Earth. Mars also has bright skies because unlike the Moon, it has an appreciable atmosphere. Getting used to that black sky may be harder for some than for others such as night owls who do not like to get up until the sun has set. For the rest of us this could be a problem.

Indoors, ceilings could be vaulted instead of flat, painted a matte sky blue and uplit from cove mounted bulbs. This would create welcome eye relief. This will be especially welcome in high dome ceilinged midroom spaces such as settlement plazas and park spaces.

Uplit matte sky blue awnings mounted on the side of vehicles could give similar eye relief to those traveling across the lunar surface. Remember, that with no air, there is no wind, so unfurled awnings of this type should be no problem.

Taking the monotony out of “Magnificent Desolation”

I have heard my Grandmother say (while in northern New Mexico) that “when you’ve seen one mountain you’ve seen them all.” For one whose soul has always been in the mountains (and not the beaches, where indeed, one wave looks like every other) I can’t sympathize with that. But unless we take care to educate future pioneers how to read the shapes of craters, their width and depth, the presence or absence of central peaks, the amount of debris on their floors and on their flanks, they might get to feeling that “when you’ve seen one crater, you’ve seen them all.” A good course in selenology and feature appreciation will make the scapes along the road endlessly interesting and thrilling. If we want our future Lunans to appreciate their adopted home world rather than be forever bored by it, we have to first learn how to appreciate it ourselves, and then learn how to pass those insights and the spirit of endless wonder in others. I have run into many Moon-enthusiasts who are really not at all familiar with the Moon’s surface features, even the nearside ones. Get yourself a good lunar telescope (wide angle, low to modest power) and start exploring, learning names as you go along.

For Lunans, perhaps the most special time to be abroad out on the lunar surface will be during what we call a total lunar eclipse. During full eclipse (the umbra period), the only light reaching the nearside lunar surface is sunlight filtered by the dust in Earth’s atmosphere which appears as an orange halo in the lunar sky. But more interesting than the sight of Earth as a lit halo, will be the moonscapes themselves, ruddy in the dim light, looking much more like Mars at dusk or just before dawn.

Surface architectures for Lunar habitats that pay homage to the moonscape yet stand proud.

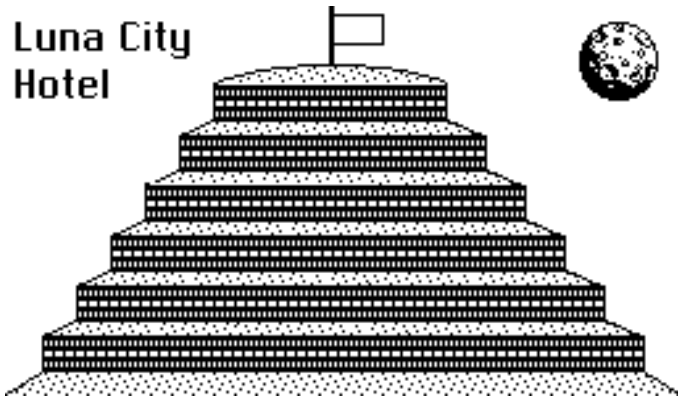
When it comes to visions of lunar settlements, two clichés persist: a complex of molehill-like, mounds of moondust covering trenched-in horizontal cylinders, and giant glass or obotanium domes encasing whole cities, skyscrapers and all. The physical problems of the latter make them most unlikely. On a world with an unbreathable atmosphere of a density comparable to what we will want to breathe, there is no problem. But that much air pressure facing vacuum outside would rip the dome from any restraints and send it hurtling spaceward.

As to the “molehill” we could conceivably give each the personal touch by simply raking it in patterns, covering it with a lighter or darker variety of moondust, covering it with lunar boulders with or without a pattern, and other means. The question is “do we want to blend in or stand proud? Our bet is that we can do both, using materials that blend in, but patterns that by sheer regularity and design, stand proud. Our architectures in so far as they show from above should pay homage to the host world, rather than be statements of defiance. If we want to be at home, we need to design accordingly.

Yet it should be possible to build multistory fully shielded pressurized structures above the surface for

hotels and other uses, that pay homage in choice of materials and colors, yet stand proud. The hotel below is a pyramid of torus stories of decreasing outer diameter with a vertical elevator-containing cylinder at the middle. An embossed caisson ring holds regolith in place to shield every level.

Luna City Hotel



A bit of Old Earth

It is one thing to leave Earth behind, but quite another to leave one's past behind. As expensive as it is to import anything from Earth, pioneer volunteers should be given a weight and volume allowance to bring along treasured heirlooms or items of great significance in one's personal history. Say 100 pounds and 2 cubic feet give or take. Pioneers could sell or trade unused weight allowances as some will want more, others need less.

These personal treasures will help tie together their former and new lives. A complete break would be unwise and become the breeding ground for neurosis or psychosis. Some things, such as photographs, can be brought along in electronic form. But actual paintings, art objects, pieces of clothing, an heirloom furniture item, must make the journey in the concrete, though with enough shape, texture, and color information some items could be recreated on the Moon as reasonable facsimiles.

A shopper's paradise? Not exactly

With imports from Earth being astronomically expensive, and with initial lunar industries having a relatively small market to serve, there will be few choices. Unless (1) we produce only basic simple "standard issue" items and (2) we design them to serve as is, *but also* to be modification friendly. Purchasers could then give them a personal touch at their leisure, or, for those with little time and/or talent, "issue" wares could be entrusted to talented craftsman and artists on commission to personalize such items for the customer during free time before or after day job duties.

Such a development could see the early years of a settlement becoming a golden age for lunar craftsmen and artists, all in the name of variety and choice, something we all value as contributing to life satisfaction. Creating a home environment that reflects our one personalities is a basic drive, creating a "safe place" in an otherwise uncaring universe.

However, anything Lunans produce for their own domestic needs are potential exports to other in-space communities (orbital hotel complexes and industrial parks for example) at a cost advantage over similar items made on Earth's surface. Thus an initially small lunar market will grow both on and off the Moon, allowing

manufacturers to expand their product lines. Meanwhile a whole suite of cottage industries may be spawned.

The role of music

We are used to making music with instruments it may be very hard to produce on the Moon. We will have no wood (we will want to recycle all waste biomass back into the biosphere), no copper or brass. However, people are enormously inventive when it comes to making music. The steel drum has to be my #1 favorite instrument (for listening, not playing) We will have glass, ceramics, other metals. Marimbas anyone! Our homegrown instruments will give lunar music a distinctive sound. Reinforcing our identification with our new adopted world.

Learning not to fear the Night(span)

No human has ever been on the Moon at night. unfamiliarity builds fear and timidity. What we fear most about the two-week long lunar nightspan is just that. It lasts for 14 and three quarter days. That's a long time to go without the heat, light, and power of the sun. It requires power storage. For some strange unfathomable reason, the idea of storing power frightens a lot of people. This is hard to understand given that our whole civilization is based on stored power, whether it be the potential power of water stored up behind a dam, or the potential power of wood and other combustible fuels. We seem hell-bent on going to the lunar poles where solar power may be available 70-80% of the time. But we will still have to store power for the 20-30% of the time. So why not learn to store power for 50 % of the time and then we can go anywhere. Fuel Cells and flywheels and other means are ready to go technologies.

We may still have to conserve power during nightspan. If we try to reorganize all our mining and manufacturing operations so that we can sequentially do the power intensive things during dayspan and the power-light but manpower-intensive things during nightspan, to the extent that such sequencing is practical, we will do just fine. This will create an operational rhythm that gives most pioneers a welcome bimonthly change of pace.

Learning to live and work on Moontime to the beat of the Moon's own rhythms

Continuing the discussion above, while commerce with Earth would be ruled by the Earth standard calendar. life on the Moon could follow the dayspan-nightspan sequence, with each month (or better, "sunth" would coincide with one dayspan-nightspan cycle, a cycle that will certainly govern mining and manufacturing. A sunth would be 29.53 days long, so a sunth-pair would be 59 days, with an added leap hour every 40 days. We could even schedule "local" weekends to that one would occur during dayspan when we need to concentrate on productivity, one at the start of nightspan, one in mid-nightspan, and the 4th just before dawn. What about weeks. All through history, attempts to assign more or less days to a week than seven have met with strongly resistance. To keep the sunths sequencing on time, we could have a free extra day three weeks out of every eight, and if those were weekend days, I predict there would be little resistance except from fundamentalists who believe Earth time pervades the universe.

We have two similar “lunar calendars” in use on Earth: one Jewish, the other Islamic. No one has figured out a way to mate lunar years (some with 12 months, some with 13) to match up with our standard 365.25 day year-based calendar. Actually as 235 lunar periods equal almost exactly 19 standard years, there is that concordance.

But the simplest thing is to use the Earth standard calendar to govern commerce and mark years, and the lunar sunth calendar to govern productive activities. ONe further note: on Earth we have 24 time zones offset by an hour each. As the Moon turns so slowly, and dawn at one location can be as much as 24.75 days before or after dawn at another location, sunth-rhythm based calendars will be purely local scheduling aids, and lunans too will use the Earth standard calendar for marking common dates and events.

The Earth standard calendar also marks the dates of the year in which meteor showers, the most interruptive of lunar weather events, occur year after year.

Bringing up the first and future generations of native-born Lunans

The first and future generations of pioneers actually born on the Moon, or at least growing up on the Moon, will take the lunar environment for granted. But unlike the situation facing young people on Earth, they must learn to appreciate the fragility of lunar settlements, not just with regard to maintaining a positive trade balance with Earth and other pockets of humanity as may arise but with regard to maintaining their artificially created mini-biospheres in good health. For Lunan youth, this will be of much greater concern ad due attention than it is for us on Earth. While our environment, suffering from lack of attention and diffidence appears to be degrading before our eyes, lunar settlement bio-spheres could hit the skids and collapse in a much shorter time frame. Inside these oases in the lunar desert, we will be living essentially downwind and downstream of ourselves. Our lunar ecosystems will need to be maintained within relatively unforgiving tolerances. Unless the health of the biosphere component of our settlements is a factor in the daily life decisions of all Lunans, the prognosis for long term survival is not good.

It will be essential that all Lunans are schooled in how the biosphere works and in what we need to do, not just as a community, but as individuals, to maintain it. Courses about the biosphere and how group and individual behavior can help or hurt in keeping it in good operating condition should be started in the earliest school grade levels, going into greater depth as students advance. On the moon, there will be a “4th R”, recycling.

Proper recycling begins with proper manufacturing and proper packaging. Assembly should be in “knock-down” fashion so that unlike components can easily be recycled separately. Manufactured items embody the energy of manufacture and elements withdrawn from nature. The less we return to nature as trash, instead of reusing, the more total energy we will consume and the more raw material we will throughput, or to put it bluntly, excrete. Our settlement efficiency index will be a measure of how little energy we consume and how little we excrete to achieve a given standard of living. Lunans must never forget that economic survival is problematic. We are behind the economic eight ball. We

need to make the most out of the least in order to go beyond survival to the state of thriving. A well-grounded realization that our are settlements are thriving, will do much to promote a sense of well-being, that we stand to turn our new world over to the next generation in good health. To the extent that we get low marks in these efforts, the rise of neuroses and psychoses may be appreciable.

The place of youth in all this.

While many believe we should postpone procreation on the Moon until we are sure that our offspring will be healthy, such a position is demonstrably absurd. We cannot know for sure that native-born Lunans will be hale and healthy until we see that the children of native born Lunans have no appreciable physical and health defects. In other words, the only way we can be sure is by taking the plunge, the sooner the better.

To forbid the first generation of settlers to raise families would measurably lower their happiness level, and their satisfaction with life on their new homeworld. It will also negatively affect the happiness level of the first generation of older pioneers, for whom grand-parenting is one of the great rewards of advancing age.

Youth can be entrusted with environmental chores. Collecting, disassembling, and sorting recyclables for instance. Picking up and sorting trash is another. Older children can assemble new artifacts and new toys out of the disassembled, sorted parts of old ones.

Young people coming of age, say 18, could be put to work in a universal service core maintaining the life support systems such as waste water treatment and air refreshing, and farming duties. This would instill in them an appreciation for what makes a settlement biospheree works. The greater the fraction of young people who appreciate such things, the more sure all can be that their settlement will survive and thrive long past their individual deaths. In short properly educated youth will mean a greater comfort and sense of security for all.

The place of retired people & seniors in all this

In the early days of outposts-no-yet-settlements, aging frontier volunteers may be “paroled” to Earth at the end of their “usefulness.” While those in their working years may not want to “carry” retired or other older citizens, such attitudes betray a great ignorance about how society works. We’ve all heard the phrase “it takes a village to raise a child.” Grandparents and other seniors are a vital part of any such village. Grandparents can help raise children while parents are busy working in jobs that produce income-earning exports.

The personal knowledge and wisdom that seniors have to impart is a vital complement to what teachers do. And there are light chores seniors can do to free younger people for more productive roles. They can do the lion’s share of needed clerical work: bookkeeping, database work, communications: the list goes on. This helps rather than hurts the overall efficiency of an all-generation settlement.

Seniors in general are happier than those of middle age. They are more satisfied with their lives and achievements. They have a better sense of what, when all is said and done, really counts in life. Without them, a settlement would soon be adrift. They are anchors.

Railroads on Mars

by Peter Kokh

Most of us are familiar with the critical role that railroads played in opening up the American West. The story was repeated, with some differences, in Canada and Australia. And with the railroads came the benefits of the Industrial Revolution. The railroads extended communications (telegraph) and by providing access to the territory they passed through, predeveloped the land.

How railroads can help

On the Moon and Mars, we aren't going to find building materials that we can "throw together" to provide shelter from the cosmic elements. We will need pressurized structures. *Pressurized modules made in a first quickly industrializing settlement can be shipped by the railroads to points along the route to provide the nucleus of new settlements.* Pressurized modules have to be handled with care. Try to haul them overland on unimproved roads and the stresses of bouncing around are going to compromise seals and maybe open cracks. Rails on the other hand will provide a smooth low-friction ride to a prepared siding complex where they can be dropped off and docked with one another to provide an instant starter outpost. Such new "town starters" might even be called "sidingments" or "sidlings" instead of settlements. Every new train could bring another module or two including ready to plug in "container factories."

Now it is going to take some time before we are building pressurized modules on the Moon. Until then, inflatable modules will cost significantly less to produce and ship from Earth, and the railroads could carry these to desired locations as well. Clearly railroads could establish chains of interconnected settlements much faster than by any other option. That goes for the Martian frontier as well.

If the human frontier on Mars advances this way from one point of origin, we won't have the problem of distant settlements isolated from one another. But if we are going to open Mars by railroading, we need to do some homework first. Top priority is production of a high vertical resolution map of Mars so that we can plot logical rail corridors where along which grade changes are slow. We may soon have a good start on such a map from altimetry data from the present and planned fleet of orbiters. We need to look for the elevation change **pinch points** are located. On Earth, these are straights and passes through which traffic funnels. Those will be critical anchors along proposed routes.

Between such narrow points the doable routing options are greater, and attention can be paid to scenic areas that would draw tourist traffic, for example. Scenic and Geological treasures along the selected route would go to the top of the list for boundary determination, and for location of adjacent visitor concession areas to set the stage for tourist and excursion companies, serving Mars pioneers.

The place of pets and "urban wildlife"

The latest evidence tracing the mitochondria trail, is that wolves transitioned to dogs in just one place, somewhere in east asia, about 15,000 years ago. Those wolves who, on spotting a human, fled out of caution from the trash dumps of early stone age villages got less food than those who were less fearful of humans. They got to produce more offspring. Humans in turn selected for more and more tame animals.

Early dogs allowed Siberians, Eskimos and Inuit to settle the high arctic. They allowed mountain-dwellers to tame mountain sheep and goats. Their bark created an early warning system and dogs quickly spread by trade to all peoples around the world. Wolves became dogs as Cro-Magnon peoples became human.

The growing percentage of people who rent housing from landlords who do not allow pets, is producing an ever larger percentage of youth growing up with no appreciation of these humanized companions. Is there a place for dogs, cats, and other pets on the Moon? There will be challenges to be sure. I once saw a cartoon with a dog in a spacesuit lifting its leg over a lunar boulder. To those who accept them, challenges become opportunities. There can be no doubt about the psychological benefits of pet ownership. The benefits for seniors is well-documented. Such seniors live longer, happier, more fulfilled lives than those who do not have pets, and are much less prone to depression and loneliness. In young people, pet dogs who love so unquestioningly, bring out the good social qualities, fostering empathy, compassion and consideration for others.

The question is how they will fit in within size and resource-restricted space frontier settlements. But only those who have not had the fortune to be loved by a pet can question that we will find a way. Speaking for myself, I would not sing up as a pioneer if my right to have a pet was at risk. I cannot imagine in a petless situation being as totally happy with life as I am now.

As to urban wildlife, some are pests, others not. We would miss a lot in a settlement with no butterflies, no birds, no fish, no squirrels. I believe we can share our frontier spaces with carefully selected species, with the balance between advantages and drawbacks decidedly in the positive. If only neutered animals were released into the ecosystem and/or to private ownership, with all breeding stock being securely isolated, there would be no danger of runaway populations.

Temporary Conclusions

We make no claim to have "covered" the field of possible mental health issues and adjustment issues that will affect future lunar settlers, Lunans. But we trust that this is a good start. Some things we have not touched upon, but have affected pioneers throughout human history, is the recurrent emotions relating to places and people they have left behind, including friends and relatives. But issues like these have already been widely studied and there is little unique in the lunar frontier situation to warrant bringing them up again.

Inevitably, some pioneers will fail to make a healthy transition and may need to return to their home world. For future new Lunans this will be much easier, and much cheaper, than for future new Martians. But otherwise, much of what we have suggested above will also apply to pioneers on Mars, "mutatis mutandis."

To the Moon!

<MMM>

Next we need to really work to define a useful “**economic geography**” of Mars. That’s a map that shows where “all” the critical resources are to be found, and in what degree of concentration. Where the elements from which building and manufacturing materials can be made are found to cluster, we have potential new industrial centers. Feasible routes that do not connect resource clusters would be options for development at a later date. These considerations are to the point on both worlds.

Routine aviation on Mars may be further in the future

Why take the train when we can fly on Mars? I do believe that we can, but I also think that aviation on Mars will be uncomfortably pushing the envelop and that because of that, it may be risky for some time.

On the one hand, we are confident that flight is possible at 125,000 feet on Earth, and perhaps that has already been demonstrated. But no one has ever demonstrated take off and landing at that altitude. The suggestion is to design Marsplanes like Harrier VTOL fighters.

It still has to be demonstrated. And unless we are to be flying only at the Mars version of sea level, say within the northern ocean-sized basin or within Hellas, and if we are not going to just skim just over the surface, Mars aircraft are going to have to be stable at pressures a lot thinner than that at 125,000 feet on Earth.

Another thing I have never heard a Mars aviation fan (other than myself) concede is that the equivalent of 125,000 feet on Earth only describes the situation in spring and fall when much of the polar carbon dioxide snow over both polar caps is vaporized. As we go into either summer or winter, a significant part of the atmosphere, as much as 30%, will freeze out over one or the other poles. If Mars flight is possible only seasonally, it will not become the backbone of transportation on Mars. Another question is to what extent will dust storms that can last months, make flight dangerous.

Now maybe we can fly even when the atmosphere is at its thinnest. I hope so, but do we know? And more to the point, will we be able to hoist heavy cargo by air? I believe that railroads on Mars will become the backbone of global transport in the early decades

Mars-Specific Design Challenges

Seasonal thermal extremes on Mars (from just over the freezing point of water to temperature lows far below the lowest ever reached in Antarctica, means that **tracks must be designed for thermal contraction and expansion**. Now on the Moon, the challenge is greater. It gets just as cold on the Moon as in the Martian winter, and in-between far hotter than the highest temperatures ever experienced on Earth on a monthly schedule. On the Moon we may have to shade the rails somehow. unless we can find an alloy with a **very low coefficient of thermal expansion**. The same will hold true of whatever we come up with to keep the lateral rail-rail separation within close tolerances: a functional **equivalent of our railroad “ties.”**

On Mars we must use elevation contour maps to identify locked, no outlet basins, which could, in a terraformed future Mars become lakes or small seas. No sense pushing tracks through such depressions, no matter how conveniently smooth.

On both worlds, we have to **design out the possibility of derailment** that would involve upturned cars losing pressurization with a total loss of life. We will be dealing with lower gravities while momentum and mass remain the same. Very **wide gauges** (rail to rail separation) and very **low centers of gravity**, even some amount of banking of curved track sections may be part of the answer. But perhaps the best approach would be to take a page from modern all **steel roller coasters with wheels above and below the rails** so that the cars cannot come off the track.

If we have to complicate rail design to meet these constraints, then track switching becomes more complicated as well. But there should be ways to do it other than the roundtable.

For passenger trains, there is another issue. On Earth our passenger cars are “vestibulated.” They have flexible accordion like passageways above the couplings that allow protected access between cars. On Moon and Mars it is **unlikely that flexible corridors could long be maintained** without a pressure loss. There would seem to be at least two ways around this problem.

- (1) restrict car to car (in Europe, wagon to wagon) passage to periods when the train is at the depot, or otherwise parked on straight level track sections. While so parked, the cars could snuggle up to one another, effectively docking as we do in space. For breathing purposes, Mars might as well provide a high vacuum, as does the Moon.
- (2) There is another option. As the railroads will be pushed through new unoccupied lands with no in place transportation infrastructures in place, there will be **as yet no overhead clearances to observe**. Nor will the rights of way be expensive to acquire. Mars, and the Moon, are virgin territories and the railroads will have the chance to set both rail gauge and clearances.

There is no reason why a Mar/Moon passenger car/wagon could not be double the width, double the length, and double the height (two floors) **able to carry as many passengers as a Jumbo jet**. Not that traffic will mandate such jumbo one-car trains at first, but the point is we should design the system so that in the future, when and if traffic warrants, we could build such capacious cars. The word “train means an coupled row of cars, one following the other, pulled/pushed by an engine car.

On the new frontiers of Moon and Mars, we have the option of starting with a clean slate blackboard, and we should take the opportunity to design for a more densely populated frontier with many major settlements. Now most people are not thinking that far ahead, but if we don’t, then we risk making a slew of unnecessary, stupid, contraceptive dead-end decisions.

The Railroad as Land Developer

Another thing worth paying attention to well in advance of the time when we starting to expand out of an initial outpost, is the role the railroad land grant system in place when railroads opened the American west. What were the good points? What points were not so good.

The Martian (and Lunar) railroads could be a major force in developing the strips of land that they passed through. This is too significant an opportunity to ignore. We will need to get it right.

Many more issues

How will railroads be powered? Nuclear power is an option that was taken quite seriously back a few decades ago by the Norfolk and Southern running between Cincinnati, Ohio, and Norfolk, Virginia. I am not sure how far along that brainstorming effort got before being abandoned. If we can make a nuke sized to run a submarine, then why not a railroad? But they are heavy units requiring water for cooling.

The tops could be paneled with photovoltaic cells. The railroad could be paralleled with communication and electric power cables. On Mars, there is another option. A small nuke on board could **process methane fuel from the atmosphere** as the train travels! This is an option not available on the Moon. This system would be self-contained, ideal for day-night **all-season operation through territories without any other infrastructure.**

Choosing between options

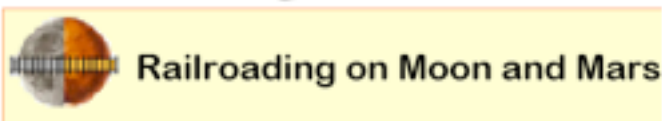
Some options will be realizable and practical before others. Yet if the most desirable option will save many headaches down the road, it's worth predeveloping. The bottom line is what percentage of the various options involves the least mass to be shipped from Earth – Earth sourcing is by far the most expensive option of all.

So we need to design a railroad system that has a lot of features with no guarantee that they will all be ready on time:

- Lowest total component mass to be upported out of Earth's deep gravity well
- Highest percentage of component mass that can be manufactured on location (English for technospeak "in situ") in time to start building the system
- Most rugged in terms of wear and tear, but also with respect to constant exposure to the Moon's naked (Mars almost naked) cosmic environment.
- Overall architecture that best supports spread of settlements as well as route-side development
- The system is the most rugged and least prone to degradation and early repair or replacement.
- The system design that best supports quick deployment of new settlements ("sidingments")

So if this article intrigued you, whether or not you have always been a train buff or a model railroader or you have simply enjoyed train travel, and if you enjoy a engineering challenge, why not join our brand new design brainstorming group: teasing illustrations on next page.

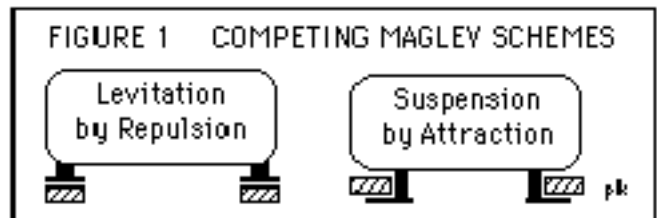
Google Groups



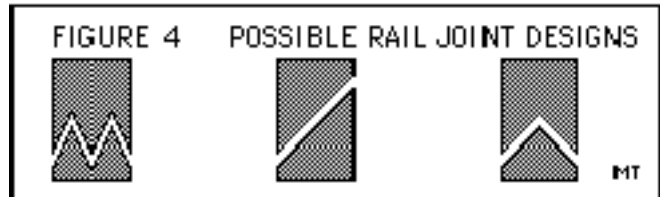
<http://groups.google.com/group/railroading-on-the-moon-and-mars/>

Calling all railroad buffs, model railroad fans, systems architects, 3-D modelers, systems integration experts, and anyone else who would like to get in on the ground floor of creating these different but yet similar ready-to-go transportation architectures for Moon and Mars. #

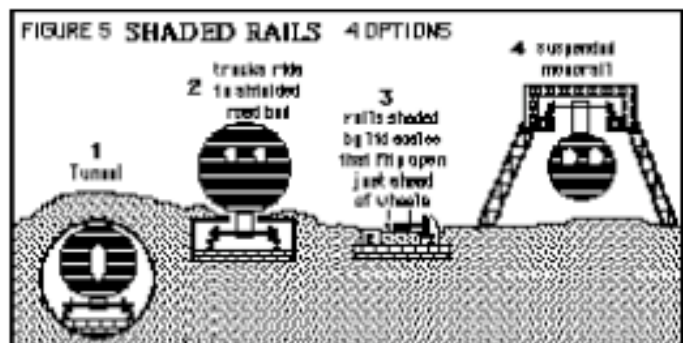
Railroad System Illustrations from 1993 Paper



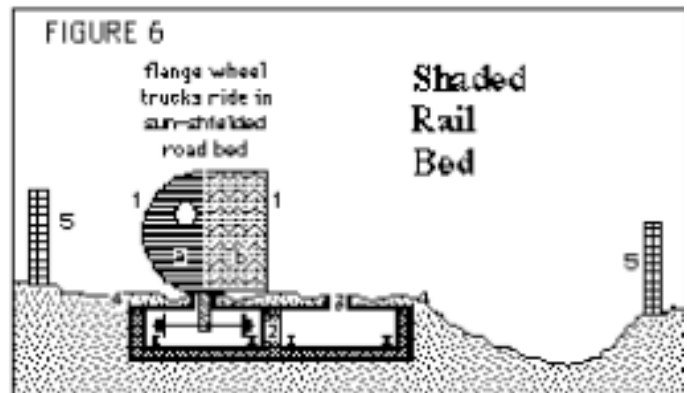
The Society has a member developing an all new Maglev system with many promising terrestrial applications



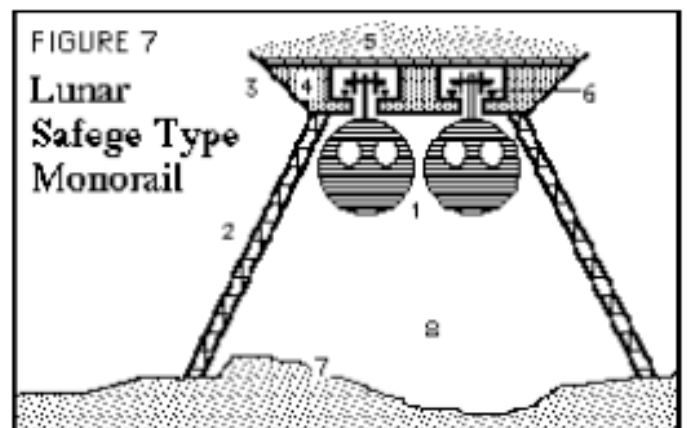
to allow for thermal expansion and contraction



Every method of rail-shading (on the Moon) brings its own advantages and disadvantages.



There are many solution to shading rails depending on latitude, time of solar day, direction of travel.



MMM Platform for Mars v. 2.0

Dare to Dare!

Revisit our original version in MMM #93 March 1996
reprinted in MMM Classic #10, p. 25

www.moonsociety.org/publications/mmm_classics/

By Peter Kokh

PART I – Basics

● Getting Humans to Mars

No rocket, no matter how powerful or fast, can deliver humans safely to Mars without a **life support System weaned of frequent “umbilical cord” resupply of oxygen and water.** Preferable and to be prioritized are biological/agricultural/biospheric life support systems on which outpost expansion and future settlements can be based. Had we now all other equipment ready to go, humans could not go along. This need underscores the importance of testing such systems on the Moon where any test failure would not be catastrophic.

● Atmosphere Mining: Methane, Oxygen, Water

Yes this technology has been repeatedly demonstrated. But there has been little follow-through. We need to perfect methane or propane fueled generators. We do have methane and propane fueled vehicles. We should tweak these technologies for use on Mars. We also need to develop/demonstrate atmosphere-derived production of organic chemistry feedstocks for the production of plastics and many other useful products. Such industry would have an export market on the lunar frontier.

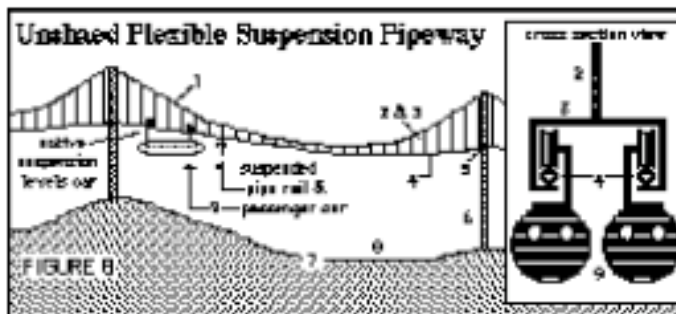
● Inflationary Growth of Human Presence

Having crews return to Earth to be replaced by fresh crews is not an efficient plan for maximum growth. We must identify the architecture and systems needed in a first Habitat landed on Mars capable of indefinite occupation. We need to identify the set of perks necessary to encourage crew to remain on Mars indefinitely, so that with each new crew ad Hab, both the physical complex and the population grows. While this idea will meet with enormous ridicule and opposition, any other plan is doomed to failure, so become good social citizens in order to survive. Of course, that must be sooner rather than later. This “Option toe Stay” is the superior tactic for the Moon as well. This is so important that the Sydney Gambit should not be ruled out. Sydney, Australia was founded by British Convicts who were forced to voluntary!

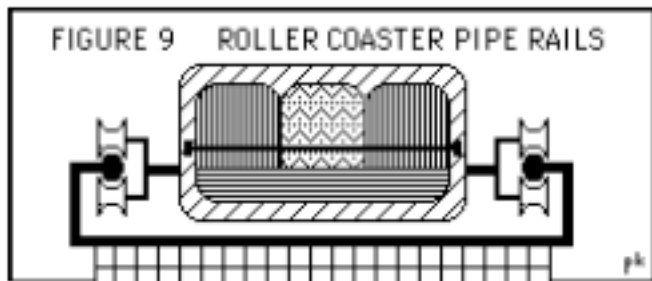
PART II – Filling in the Holes in an Economic Geography of Mars

http://en.wikipedia.org/wiki/Economic_geography

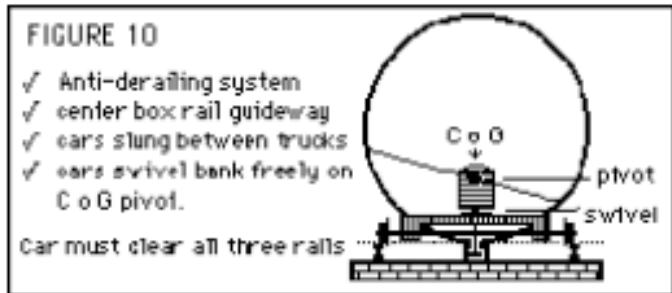
“is the study of the location, distribution and spatial organization of economic activities across the **Earth**.” To this writer, that is not an adequate definition. Economic geography includes a set of maps which show where resources of economic significance are to be found. It also should identify geographic, geological, topographic features and other physical features of potential economic significance, including features that affect transportation routes (navigable waters, straights and passes, etc. In application to Earth, it also identifies population density, relative use of transportation routes, industrial concentrations and more. For Mars, as uninhabited we are concerned with potential features that will affect how a human frontier will expand globally, as well as what choice of sites will optimize future expansion.



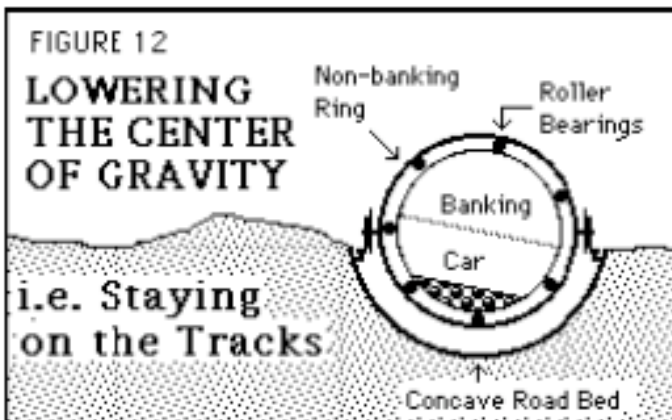
Monorail systems ^ are ideal in rough and scenic terrain



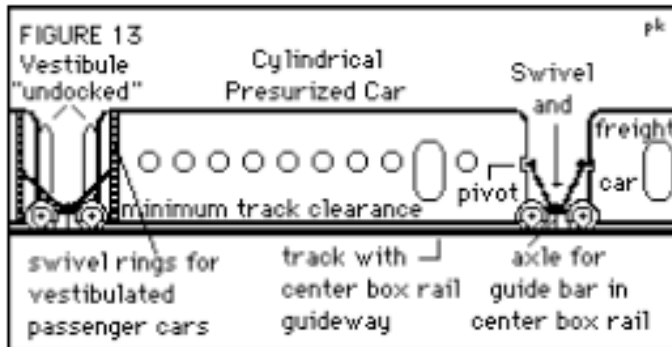
Derailment must be engineered out of possibility as ruptured cars/modules would mean instant death.



Center box rail, ability to “lean” minimize derailments



Above: ultimate in derailment proofing, cog below rails, cars swivel into proper lean in turns.



- **Mars Permafrost Explorer** — The opportunity to pre-test such a probe in Earth orbit to improve our knowledge of terrestrial tundra resources, makes this an easy sell. While current orbiters can locate water ice very near the surface they cannot identify ice or liquid aquifers at the depth at which they are more likely to be found.

Once we have mapped these resources, ground truth probes which can drill down to identified reservoirs, and characterize the water resource as to salinity and other features are in order. Siting a first outpost without such a comprehensive study would be plain stupid.

- **Mars Lavatube Explorer** — We have already identified lavatube entrances on the flanks of Olympus Mons. Lava tubes of a scale larger than terrestrial ones but smaller than Lunar tubes are likely to pervade the great shield volcanoes on Mars as well as the entire Tharsis Uplift. The opportunity to pre-test such a probe in Earth orbit to improve our knowledge of lava flow terrain, makes this a logical priority. We could re-fly such instruments around the Moon where tubes lie deeper below the surface. The results could be far less important for geology than for future Mars settlement scenario options. Ancient near-surface Martian limestone caves could also be identified. Meanwhile robotic mobile probes should be targeted to already identified tube openings.

- **A High Vertical Resolution Topographic Map of Mars**

With accurate elevations, a contour map of the entire planet potential watershed basins and their downward linkage, as well as basins that have no outlets. No sense in putting a settlement in a location that might someday be under water!

- **A global network of weather stations**

A better knowledge of area weather patterns through all seasons over several years would help crews and pioneers prepare for weather related eventualities.

- **A global seismic activity monitor station network**

There is no wisdom in continuing to assume that Mars is geological dead. We should also look for any “hot spots” that could be a source of geothermal energy. It serves no purpose to assume the answer is know when we could check.

- **Potential resources on Phobos & Deimos**

Russia’s probes Phobos 1 and Phobos II both failed to reach their target. Fortunately, Russia’s current **Phobos Grunt** (Phobos Soil) mission may give us some answers. Resources developed on one or both of these moonlets could not only help open the planet itself but provide valuable exports to the Lunar frontier, earning credits to be applied to purchase of badly needed equipment and supplies from Earth. This knowledge will be a cornerstone of any realistic “Economic Case for Mars.” Relying solely on handouts from Earth is a sure invitation to wholesale cessation of support.

We thought at one time that these moonlets were captured carbonaceous chondrite asteroids. Now we are not sure. If so, this would be a supply of hydrogen, carbon, and nitrogen high up the shoulder of Mars’ gravity well, that could routinely be shipped to the Moon. We need to know. Any attempt to bypass these moonlets in developing Mars, grounded solely on impatience, will bite us in the butt sooner or later. We need to know what resources are there so as to plan intelligently.

- **Outline of Mars Economic Geography topics:**

- subsurface water / ice
- iron, other metals
- thorium & uranium
- gold, silver, platinum, copper, zinc
- cementacious/silica materials/salts
- regolith/sand depth over fractured
- bedrock/basalt
- sedimentary areas, sediment depths
- topographic clues to transportation corridors
 - gaps, passes for roads and railroads
 - aqueduct/canal/pipeline routes
 - future rivers / lakes
- atmospheric pressure seasonal variations
 - Mons summits, Tharsis plateau
 - Boreal Basin bottom, Hellas, etc.
- outgassing
- geothermal areas
- likely lavatube areas
- tourist sites – historic & scenic sites
- geological wonders

Part III – Needed Equipment

The excuse that we don’t need something right away, surely to be the mantra of those only interested in exploration of Mars (satisfying their own set of scientific curiosity itches) and not interested in Mars as a future human frontier, if not entirely hostile to that prospect, is no excuse for those of us who do care, to leave it to NASA whose interest is minimal and peripheral to develop equipment needed on a Mars Frontier.

- **Mars Aviation** – NASA has indeed looked into small drone aircraft for use in exploration. We believe that flight on Mars is possible. But takeoff and landing from an equivalent altitude of 125,000 feet on Earth has as yet not been demonstrated. If we are to rely on passenger & cargo aircraft to facilitate travel and trade on Mars, we should be thinking of how we can develop the needed technological advances here on Earth.

- **Mars Railroads** – Railroads were essential to the opening of the American West, of Canada, Australia, and Siberia. It could be so on Mars. See RR articles this issue.

- **Solar Sail “Pipeline” Cargo Deliver Systems** – The descendents of Cosmos 2 provide the best option to byappassing the 25+ launch window intervals between Earth/Moon and Mars. In pipelines, how long it takes something to go from source to market is irrelevant as long as something is always entering the pipeline and something is always coming out the faucet at the end. This is a system vital to tapping asteroid resources as well. How can we help? Supporting the Planetary society Cosmos 2 Solar Sail project with donations is certainly one way, for those of us technically challenged!

Part IV Mars Analog Activities

It was a deep honor, a great privilege, and a matter of pride to have served on two crews (# 34, #45) at the Mars Desert Research Station in Utah. I have great respect for the program and detractors have taken many cheap and unfounded shots out of ignorance and lack of first had knowledge. But my enthusiasm did not blindfold me to the limitations, and failures, of this project.

The Mars Society was founded on the belief that Mars is the best location for a second basket in which to

put human and Earth life eggs as a hedge against the possibility that human civilization could collapse on Earth, whether from a possible untimely asteroid impact, from human strife, or from total collapse through overpopulation and runaway exhaustion of resources.

All the same, these two stations, in Utah and on Canada's far north Devon Island, are totally designed to demonstrate Mars exploration tactics only. The vertical Hab standing above the Mars surface, fully exposed to temperatures that can range at the equator from just above freezing to lower than anything we have experienced in Antarctica. Such an architecture invites catastrophic collapse of any Mars exploration mission of anywhere from six months to up to two years. What is easiest to ship and land is not necessarily the easiest to maintain on Mars. Nor is the solitary Hab structure designed for expansion. What should be the demonstration goal of the project are technologies that make expansion towards a more comprehensive permanently manned outpost leading to real first settlement.

What is needed is not the phase out of this analog program, but a whole new start based on a whole new philosophy. Perhaps some of the design and research objectives under consideration for a proposed Lunar Analog Research Station will produce know-how and experience useful on Mars.

Part V- Building an Economic Case for Mars

"Mars First/Only proponents are fond of pointing out that Mars has a more complete set of resources on which to base a sustainable frontier. That is partially true.

Partially, because it will be a very long time before the Martian Frontier could sustain itself should all resupply and supply of things that the pioneers could not yet provide for themselves somehow cease whether from economic collapse on Earth or international weariness of supporting the young Martian frontier. To create "An Economic case for Mars" means identifying realistic potential export products to earn credits to pay for imports. Outside of potential but as yet uncertain exports of volatiles from Phobos and Deimos to the lunar frontier. we have not seen a single realistic export suggestion. Gems not found on Earth? Unlikely, and purely speculative. Medicinal plants that grow only in Mars Soil? Again pure speculation. Income from Earth tourists? Who but the rich terminally ill are going to take two or three years out of their lives for the round trip experience?

Partially, because three other resources, none of which Mars offers, are really hard to do without. We all know what they are: "**Location, location, location.**" The Moon has it, Mars does not. Like Japan which lacking steel, coal, and rubber, developed the entire Pacific rim for markets of raw materials and markets for exports created from these raw materials. The Moon, a handier source of materials for building out the human presence in LEO and GEO, and of capital goods for Phobos, Deimos, and even Mars, is poised to become the Japan of Space. Japan has proved that by far the most important resource is not physical at all. It is **resourcefulness**.

In a future in which both Lunar and Martian frontiers are expanding apace, there will be a trade economy between Earth, LEO, GEO, the Moon, and Mars in which a greater Mars, Mars PhD, will have a place as a supplier of goods to the Lunar Frontier that will earn them credits for purchasing equipment from Earth. Prevent the Lunar frontier out of blindness, and perish.

It is in the Moon Society's best interests, and in the interests of all who want to see a health lunar frontier develop, **to help develop a strong Economic Case for Mars** – even if Mars enthusiasts don't care to do it themselves, or scorn our help. The Moon and Mars will either thrive as trade partners or []=both whither on the vine.

Accessing the Asteroids

Isn't Mars closer to the asteroid belt? This point that has been made by science fiction writers from long before the Space Age began. It is both true and a curse. Why? Because of a catch 22 of celestial mechanics:

The closer two orbits are to one another in period, the less frequent the launch windows between them. And the corollary: the further apart two orbits are in period, the more frequent the launch windows between them.

This may look like a cruel trick, but we could not have solar systems without it. Mars greater proximity to the Belt, but this is actually a disadvantage that will make the Moon the preferred transportation "hub" of the asteroid belt.

Observatories on Mars or on Phobos or Deimos can help identify and keep track of asteroids and astrochunks that could threaten Earth. So that is one investment we ought to make.

So how do we build the Economic Case for Mars? It would be deceitful to say we have a plan. But we have outlined the starting point: **Promote completion of the Economic Geography of Mars:** A chemical and physical resource map will help us plan where first settlements should be located, and facilitate global expansion.

Shouldn't a first outpost be sited near the places of most scientific interest? Yes if you are self-destructively impatient. In the end we will explore Mars much more thoroughly if we have a permanent human frontier on Mars, than we will if we rely on hit and miss landers and rovers. Impatience always bites one in the butt.

We first gave a presentation on the need to build an Economic Case for Mars at ISDC 1994 in Toronto at the request of Chair Paul Swift. There was no response from the mostly pro-Mars audience. Nor do I expect more input from Mars fans to this new report. That's why we Moon-enthusiasts must take the lead. It is in our own best interests to do so. We do not now have the needed information. We have pointed out that a Mars alone (damn Phobos and Deimos) approach is doomed. We are trying to jump start brainstorming on potential Mars transportation infrastructures: aviation and railroads. We have tried to point out that the Mars Analog Research program is not optimized to produce the best results.

For now, the most helpful thing we can do to ensure that the Mars Frontier gets off to a good start is to keep on working on the Economic Case for the Moon. The lunar frontier will be a cheaper source, once capital costs are amortized, of goods for Mars, as well as the best source of field-tested hardened pioneers, for whom, Mars will be "a walk in the park." <MMM>

Look for a Mars-dedicated issue of Moon Miners' Manifesto every March!

Why? Because it is our firm belief that both a Lunar frontier and a Martian frontier will have a better chance at Economic Viability as trading partners than either could have on its own. PK

Expanding Beyond the first Outpost: Aspects of An Early Lunar “Community”

by Fred Hills <FredHills7@aol.com>

A Starter Community:

A small group (say 30 people) should be able function successfully as a community if certain conditions are met.

Each person can be alone some of the time (e.g. I am, at this time, alone in my home office while the rest of the family is sleeping.)

Sleeping space is subdivided (i.e. not more than 4 people to a space). e.g. The US Navy designs ships with 2 and 4 person state rooms, and a bathroom for each. There is desk and closet space as well. Compact and efficient, much like college dorms.

Normal work groups are small and groups may vary over time.

Physical space is divided into compartments so that groups function with minimal awareness of other groups. (i.e. work spaces, sleeping spaces, eating space, exercise room, etc. are isolated to some extent.)

Communication:

Communication with Earth: Telephone, television, radio and internet available 24/7.

A cell phone tower will provide communication between people as well as machines in the base area. As the actively used area grows more towers can be added.

Inside work:

Office work, laboratory work, managing/controlling outside work.

Maintenance: Lots of it.

All the office and life support equipment in the base will have to be maintained. All those machines running around the lunar surface will need help as well. They could brought into a repair shop through a suitable air lock for service.

Outside work:

Construction and mining done with remotely operated machines controlled from the base or even by operators on Earth. Remotely controlled equipment provides a vicarious experience and should be sufficient for most tasks.

Human operated machines will probably be needed, and a small cab could be provided. (Think of those folks that spend their day operating a tower crane at a construction site.)

Out-vac work:

Workers in space suits may be about as rare as scuba divers on Earth, although some jobs are outside. The expense, inconvenience and time needed is burdensome. Space suits will be very expensive and require a lot of maintenance. Outvac workers will have to be extensively trained I think as were the Apollo astronauts. (I have been snorkeling in the Caribbean and scuba diving in Hawaii. Both fun when one happens be in a suitable location. But scuba diving is expensive and can be dangerous.)

Production:

Oxygen, aluminum, building blocks (sintered regolith) and other materials will be needed to expand the facility without massive amounts of material from Earth.

Transport:

Robots can move supplies, outvac equipment, etc. around, and pressurized vehicles (minibuses?) can move people around.

Out-vac workers may use vehicles similar to Apollo Moon buggies.

Facilities: may cover a fairly large area.

Experiments strategically placed

Mines wherever conditions are best and reasonably close.

Road graders can create smooth paths for vehicles between facilities and work areas.

Training

Education and training is likely to be an ongoing activity.

Food:

A learning experience: Humans will have to learn how to live on the Moon as they go. (American colonists could rely on Indians to find good water, fishing, hunting, and places to gather wild fruits or vegetables We won't have that luxury on the Moon.)

Plants on Earth evolved to grow according to the seasons. Since the lunar day doesn't match any of the Earthly cycles we will presumably have to develop plants that do well on that schedule. Plants can also be grown under artificial light during the lunar night.

Entertainment:

Group activities should also be encouraged: e.g. dancing, concerts, movies, and plays (as in colonial times). This requires significant space. There should be ample time for this during the lunar night even as 'night work' continues. <FH>

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Editor's Notes:

While in general, MMM articles on civilian settlements have looked further into the future, we have published a series of articles dealing with what will be involved in breaking out from the constraints of an early science outpost, to begin crossing the divide towards civilian settlement: “**The Outpost Trap: Technologies Needed for Breakout**” – Readers will find these articles in the following recent issues:]

MMM #198 September 2006, pp. 3–6. Parts 1, 2, 3

MMM #199 October 2006, pp. 3–8, Parts 4, 5, 6, 7

MMM #200 November 2006, pp. 3–6, Parts 8, 9

Note: All three of these issues can be freely downloaded (without username and password) in pdf file format, from the following directory:

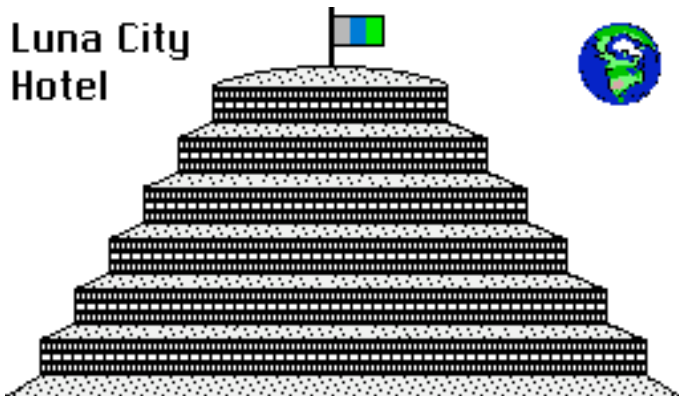
http://www.lunar-reclamation.org/mmm_samples/

It is our firm conviction that we will not get from here to there unless each phase is designed “to be pregnant” with the next phase. While NASA does foresee future developments, it is designing only what the budget will allow, and this shortsightedness is likely to end in a *cul de sac*. PK

Revisiting a Sketch for a Luna City Hotel

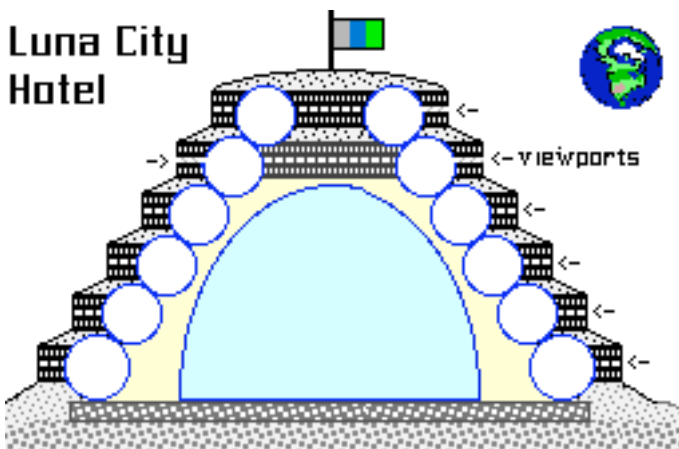
by Peter Kokh

Luna City Hotel



Above: The original illustration is from MMM #111, p. 4 Lunar Skyscrapers: Shattering LoExpectations, Dec. 1997

Luna City Hotel



Above: Rerendering showing interior Cone of stacked torus rings, two floors each. They would be supported by a conical truss system which incorporated elevator shafts on an angle at four points: N, E, S, W. Within this conical complex is an ovoid dome with translucent, not transparent, glass with a sky blue cast. Lighting would be outside the dome but within the cone structure. Inside would be a multilevel park like setting incorporating waterfalls and fountains, various trees, and a variety of plants. **The exterior of the hotel** shows caisson rings that are filled with moon dust for shielding the hotel. Window openings through the caisson are provided at intervals, and though the path is direct, very little cosmic rays will make it through these narrow openings. Keep in mind that the hotel rooms are for occupants on short stays. **Atop the hotel** is a flag. There is no official lunar flag, nor a Moon Society flag. We used the ad hoc flag design that flew at the Mars Desert Research Station during our "Artemis Moon base Simulation in early 1996. It is a tricolor, following suite with the Mars Society flag, with gray (regolith), blue (water), and green (vegetation).

Lunar hotels may not look like this, but our purpose was to stimulate thinking, and show that fully shielded structures could be designed to "stand proud."

Now it's your turn!

MMM invites the architect in you to submit other "skyscraper designs." We'll publish the best of them and give you full credit. Maybe we'll make a model of the winning entry for exhibit!

<MMM>

Protecting Lunar Surface Facilities from Sandblasting by Landing Rockets

by Peter Kokh

www.space.com/scienceastronomy/080212-st-lunar-sandblast.html

The evidence

When Apollo 12's Lunar Lander *Intrepid* set down as planned, just 600 feet from Lunar *Surveyor 3*, the visiting astronauts (Conrad & Bean) photographed *Surveyor* from all angles and took back the lander's camera an scoop for inspection back on Earth. It was clear that the spray of fine dust kicked up by the landing *Intrepid* had sandblasted clean a dark hue over the rest of *Surveyor* due to exposure to cosmic radiation. Landing photos showed that the LM exhaust moved rocks up to six inches in size. This spray had to have traveled at a third of the speed of a bullet, 1,300 ft per second.

The verdict

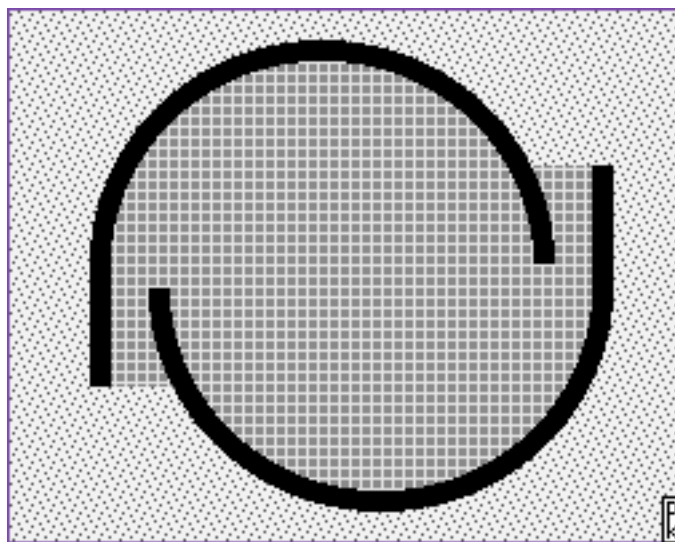
The implications are that equipment delivered on the Moon including habitat modules, should be protected from the exhaust of future landers. Modules covered with regolith for shielding purposes will be safe if their airlocks do not face the launchpad. But in general we need to have landers arrive and depart out-of-line-of-site. And, of course, personnel waiting for the landing craft must be protected behind some sort of bunker wall.

Neutralizing the problem

One idea is to put the space pad inside a suitably sized crater. Craters smaller than several miles in diameter tend to have a bowl-shaped floor. So the crater floor would have to be graded level and cleared of rocks and boulders. Compacting the surface and passing over it with a magnetometer to sinter it into a crust could help.

In the absence of a suitable crater, a berm could be constructed with a simple bulldozer, given time. But if we are looking at continued growth of the site complex and increasing traffic, building a proper spaceport facility becomes a priority.

In the illustration below, a wall of sintered blocks surrounds the launch pad (of whatever size) with a pair of buffered entry points for cargo and personnel vehicles. The graded, compacted, and sintered floor is covered with thick cast basalt tiles. The inner surface of the surrounding walls might be covered with such ties as well. Of course, there will be those who say that this just shows that "doing the Moon" is too difficult, unrealistic!



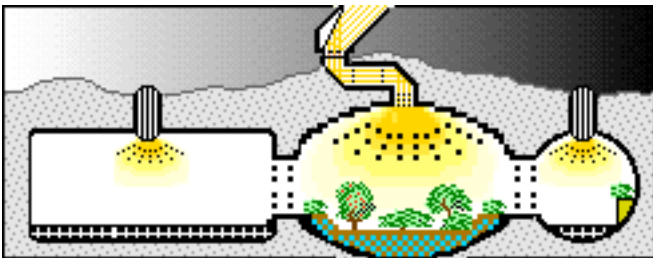


IN FOCUS Earth Day 2008: Taking the Green Spirit to the Moon

We all know that at best, public interest in space is *shallow*: “a mile wide, and an inch deep.” Among young people and among the growing percentage of those who are, or are becoming, “environmentally conscious,” one of the most frequent reservations we hear is this simple challenge: “Why should we go to the Moon (or Mars) and trash them the way we are trashing the Earth?”

It is not to our credit that too often the response is to dismiss the question as well as the questioner. If we are going to build support, as we must, so long as we are stuck with a tax-supported program, we need to take this on this challenge with due respect. To fail to do so, only confirms the plaintiff’s suspicions. Not exactly to our credit, too many space enthusiasts consider environmentalists the enemy, instead of natural allies whom we must do our best to court. *It is possible!*

If we love our own vision, we owe it to our own dreams to get past this silly pettiness. Nor should we pout and wait for “them” to make the first move towards reconciliation, cooperation, and collaboration. Unless we take the lead, we can forget about building *significant* public support. We already share one most significant goal in common: preservation of Mother Earth for future generations. We come at it from different perspectives, and from different cultures. This gap can be bridged!



What follows is a brief outline that our conversation with the Greens, and with ourselves (a guideline to considerations we must address in our own plans to advance the day when civilians will be living on the Moon, engaged in pursuits which will assist those on Earth to survive our current crises, crises probably typical of “adolescent” intelligent civilizations. Later in this issue, we will address these points in paragraph form, leaving fuller treatment to individual future articles.

Read:

<http://www.moonsociety.org/projects/projectteams/enviro-space/PKGreenSpaceConf.pdf>

Points to Make with the Environmentally Concerned

(A) Mining concerns:

Mining methods: most of the major and minor elements we will need are found in sufficient abundance in the rock powder blanket that covers the Moon’s surface. The need to strip mine or mine deep underground is very minor.

Tailings: By conducting a cascade of mining sequences where removal of one needed element makes the tailings that much richer in other elements, we constrain our regolith mining operations and greatly reduce the total of energy input needed, and then using the final tailings residue for secondary construction uses.

(B) Recycling concerns:

Recycling spent energy; Everything we make embodies the energies needed to produce it. We can recycle that energy by recycling the materials, as items are replaced.

Industrial design: We can choose assembly methods so that diverse materials do not contaminate one another and can be easily separated for proper recycling.

Economics: to become economically viable, we need to make maximum use of everything we produce, and that can be done best by a comprehensive recycling system. This maximizes use, minimizes throughput (resources in/discarded waste out), minimizing our lunar “footprint.”

Enterprise: A very high percentage of entrepreneurial opportunities for pioneers will be in the area of reusing materials no longer serving their original design purpose.



(C) Concerns raised by our bad record on Earth:

Postponed urgency: Our biosphere (atmosphere, hydrosphere, flora and fauna) is so vast until recently it has been doing a good job of handling of recovering from our environmental sins. We postpone solutions to the next generations (for which we will be condemned.) On the Moon, we must live in self-contained mini-biospheres, essentially living downwind and downstream of ourselves. What we do wrong will hurt us immediately. We learn to live in harmony with our mini-environments, or we will quickly get the “game over” message. The lessons we learn can be exported to Earth. – PK

“NASA is not about the ‘Adventure of Human Space Exploration,’ we are in the deadly serious business of saving the species.” – John Young

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

We have to start over, from scratch, This time with a plan! – Simon Cook



"Anything worth doing is worth doing well"

Returning to the Moon

I: Bursting Apollo's "Envelope"

So many really basic things were left undone!

by Peter Kokh - Reprinted from MMM #88 - September 1995

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

⇒ Twelve men set foot on the Moon. Yet none of them slept in a bed there. The LEMs had only hammock-slings. All twelve walked in one sixth gravity, but only with cumbersome pack-laden pressure suits - the pressurized LEM "cage" was scarcely big enough to pace back and forth in place. So no one experienced what it is like to walk in lunar gravity, not really.

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

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

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

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

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

2. A New Beginning

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

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

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

(1) *If we leave a habitat structure on the Moon*, perhaps returning to an awaiting orbiting ferry (serving a function like Apollo command modules) ascending on a *cabinless* platform (not unlike the Apollo rover) protected just by space suits.

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

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

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

3. Then What?

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

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

(7) *We might try some brief nightspan sorties* outside the station. That means headlights, that means lubricants that can

take the cold - or magnetic bearings. That means heated space suits or an infrared radiating cage or a minimal cabin.

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

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

4: Exploring Metaphors

For want of a better name!

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

Base: (1) a bottom support on which a thing stands or rests; (6) *the point of attachment*; (7) a starting point or *point of departure*; (9) a *supply* installation that *supports* operations

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

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

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

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

Outpost: a station established *at a distance* from the main body [of humanity]; a post or settlement *in a foreign environment*.

Station: (6) a place *equipped for some particular kind of* work, service, research, or *activity*, usually semi-permanent

While all of these terms are applicable as far as they go, none of them are especially *instructive*. And most of them are static, not suggestive of leading anywhere, *thus requiring separate justification of any further steps*, and thus likely to become self-limiting. We suggest that we space advocates who really want to see human out-settlement wean ourselves of such terms as Moonbase, Lunar Outpost, etc. and *look for more pregnant terms that suggest a sequence of phases that lead to something much more*. If we find better terms we must popularize them and thus *alter the culture* in which space futures are discussed.

Words are not neutral

We must pay attention to their downside or self-limiting connotations. We are in a battle for the soul of humanity. We have to stop using the weapons the enemy gives us and forge our own.

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

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

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

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

“Interface Beachhead” & “Settlement Incubator”

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

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

5. Our Presence must be more than Serial

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

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

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

In this light, we need to consider which initiatives, NASA, International, Commercial, etc. that deserve our support. *We owe it to our own dreams to decide wisely. MMM*

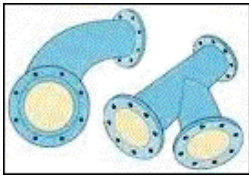
[Early Lunar Industry]

HEWN BASALT PRODUCTS

By Peter Kokh

Cast Basalt

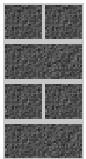
In a past article [MMM #135 - May 2000, p. 7] we have talked about "Cast Basalt" - basaltic moon dust from the lunar maria or "seas" (of congealed lava sheets) that, given ample precedent here on Earth, can be made into durable, functional, even beautiful tiles for floors, countertops, walls and more. Further, cast basalt is highly abrasion resistant. cast basalt floor tiles should resist being dulled or scratched by any moon dust that gets into living spaces.



This same quality has led to a major industrial use of cast basalt liners for material handling chutes and pipes and associated fittings. Both these uses will be most helpful on the early frontier.

Hewn Basalt

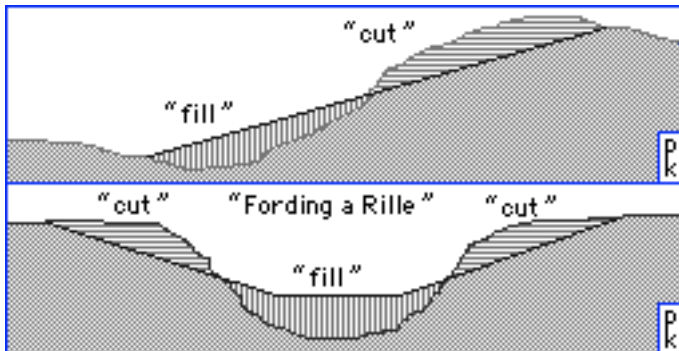
Hewn basalt is chemically related, but structurally different product that may precede cast basalt as an early frontier industry. Here we are using not pulverized basaltic moon dust, but solid basalt, that can be cut into blocks (and tiles) for many practical uses. Hewn basalt blocks of various sizes and shapes can be used to build columns, retaining walls, and shade walls. They could be cut on angles to build arches. Such blocks would serve many practical external uses in unpressurized spaces.



Finding solid, minimally fractured basalt

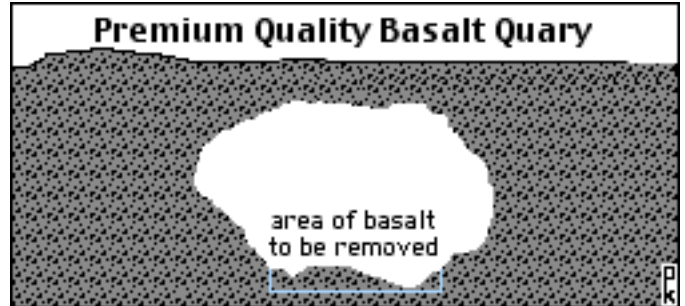
The pulverized and impact gardened "regolith" blanket is on the order of 2-3 meters/yards thick in the basaltic maria. If we scrape off this top layer, we should reach fractured, increasingly pure basalt. The further down we go, the less numerous the fractures.

Another opportunity will come in road construction, where to smooth out hill, a cut and fill operation may be needed. The lower part of the "cut" could expose fractured, more or less pure basalt.



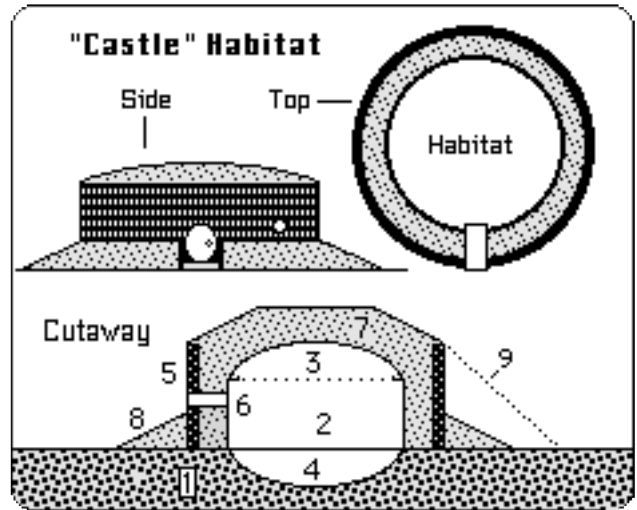
Basalt Blocks hewn from Lavatube floors

Where a settlement area includes a nearby intact lavatube, it is likely that, in the process of getting it ready for use, whether as a spacious pre-shielded industrial park or warehouse or agricultural space, or even as residential space, we will want to smooth out irregularities in the tube floor. The tube floor is likely to be relatively free of fractures. Thus the various sized blocks we cut out are likely to be of a superior quality.



It is basalt blocks from lavatube quarries that will be in most demand. Satin finish quarried tiles may be an architectural material of choice for some applications as it will have a different look from cast basalt tiles.

Hewn basalt blocks may be applied to exteriors of private, individually shielded homes, as retaining walls for moon dust fill, to give the exterior mound a controlled shape as a sign of wealth and prestige.



KEY: (1) surface, minimally excavated to nest the rounded bottom of habitat hull; (2) Habitat Hull, in this case a squat vertical cylinder with round end caps; (3) vaulted, cove-lit ceiling; (4) "basement" area for utilities and systems and extra storage; (5) the "castle" rampart retaining wall made of cast basalt blocks with openings for narrow windows; (6) shaft for "window"; (7) regolith moon dust shielding and (8) berm; (9) slope of shielding without a retaining wall

Hewn Basalt Blocks as Sculpture Medium

Carving basalt blocks into sculptures of all sizes is an age old craft, practiced in Egypt and elsewhere. The columns of temples and other great buildings were often carved from basalt blocks.

But smaller sculptures and decorative items were also carved from basalt, a wonder, as we now have much superior tools such as titanium-tip chisels. Given the lack of other natural carving materials on the Moon, cast basalt statues and sculptures are sure to be a mainstay of

lunar frontier homestead décor, as well as on a larger scale, of larger sculptures for public places, both within pressurized spaces and out on the surface in prominent locations. Art will be one major way in which we put a human stamp on the moonscapes surrounding our settled areas.

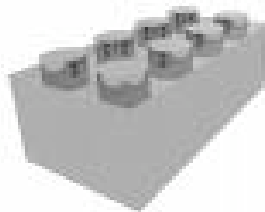
Both for curiosity and to use for “show and tell” the writer bought this sample, a Scarab, online from a shop in Egypt. The photo does not do it justice!



Cast Basalt Blocks vs. Sintered Blocks

Perhaps the first manufactured building material lunar brainstormers came up with is simple blocks of moon dust compacted by vibration in a mold, then sintered into a solid by microwaves. Such sinterblocks would look a lot like our concrete sinterblocks, and have a similar density and cohesiveness (or lack thereof.) It is certain that sinter blocks will be cheaper to produce and perform well enough for some purposes. In other applications, where hardness and density and visual quality are important, hewn basalt blocks may have the edge. At any rate, it is important both to support a greater variety of uses as well as to provide customers and consumers with choices, to develop all the near-term options.

One advantage of the sintered moon dust block is that, as it is made in a mold, it can have a shape other than that of straight saw cuts. A sinter block can have indentations and protrusions, not unlike a lego brick, so as to stack snugly and in line, one over the other and in staggered rows. Sinterblock will be easier to hand cut.



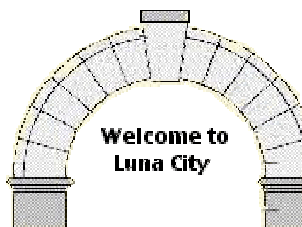
Make it Grand!

From crude and rustic to Romanesque or Gothic formality to almost spiritual simplicity and elegance, arches have been a favorite way of marking the entrance to a human settlement. Paris’ Arche de Triomphe and St. Louis’ Gateway Arch are examples of the variation.

A freestanding arch could mark the approach to the settlement main gate, or straddle the main road from the spaceport to the town. And what more refined material than hewn basalt, marking our ability to use lunar materials to state proudly, “we are at home!”

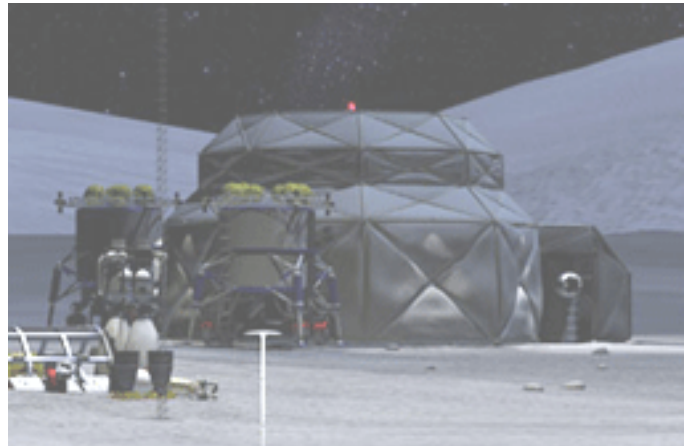
A new Stone Age

Does it seem odd that our initial efforts to use lunar materials will use a “stone age material? It is what we do with it that counts. Most of all, basalt is a material that is of the soul of the Moon. <MMM>



SADDLEBAG SHIELDING

For a Vertical Moon/MarsHab



[Brightened Detail of Pat Rawlings’ Painting s245]

By Peter Kokh

It is arguably easier to land a vertically designed habitat than to bring along a crane to set down modules of the horizontal persuasion, even though it is quite a bit easier to shield the latter. The vertical design has a long history that includes TransHab and the “double tuna-can” Zubrin MarsHab. This configuration type appears in many NASA concept illustrations.

But in the *real* world, we do need to cover *any* habitat with moon dust or Mars dust shielding. Yet, it is desirable to avoid a large footprint hill. Natural regolith slopes are limited to 30° slopes, though tamped down as it is piled up, the regolith, being composed of angular particles, will support slopes of 45°, *still awkward*.

We can constrain the pile by erecting a circular wall around the habitat, using blocks made on location of sintered regolith, or made out of sandbags. Either will be labor intensive and delay the commencement of routine operations. Another way to get the job done with minimal fuss, is to bring along a saddlebag shape-following tent of sorts. This would be lightweight in comparison to the number of needed sandbags and filling equipment, or the equipment needed to produce sintered blocks.

Of course, we must choose a fabric that will wear well under cosmic radiation, raw ultraviolet sunlight, and micrometeorite rain. Rawlings’ illustration suggests that this is something NASA has looked at.

On the other hand, if we are going to keep adding additional modules in an open-ended expansion plan, this shielding method would be money misspent; and on site production of shielding constraint systems will be something we should introduce as soon as it is practical, that is, when we have all the precursor equipment and technologies in place.

Yet, for temporary locations, say of construction camps, where crews will be on site for temporary periods of a few months or more, the shape following habitat moon dust constraining fabric structure seems a good idea, especially if it can be emptied for movement, and then set up and filled at a new location, again and again.

Now this is a tall order for designers of such a system! Sounds like a great subject for an architectural system Design Competition, funded by NASA!

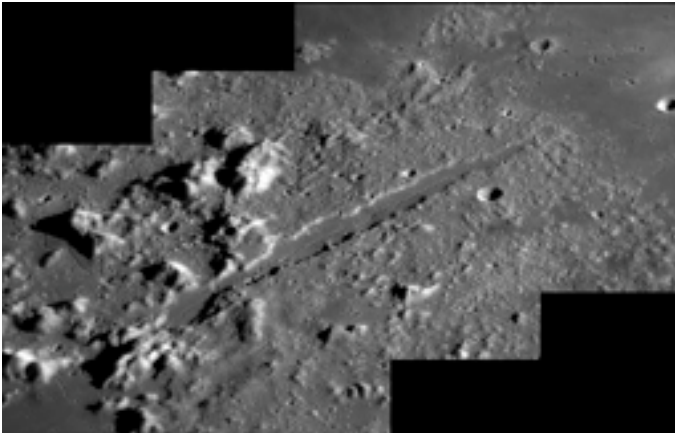
Comments welcome.

<MMM>

The Moon's Alpine Valley: Scenic Treasure vs. Vital Transportation Corridor

By Peter Kokh

It would be ideal if we could identify all the most scenically and geologically "special" features on the Moon and classify them into those that can be visited but not developed ("leave but footprints, take but photos") and those "common" and "mundane" enough to warrant consideration for development. Ideal! Unfortunately, sometimes very scenic areas, by their very nature also happen to be "in the at" of logical traffic routes, or, as in our case in this article, a logical transportation route precisely because of what makes it scenic and special.



Above: a close-up mosaic view of the Alpine Valley

Below: The setting, between Mare Frigoris (north) and Mare Imbrium (south)



Mare Frigoris (Sea of Cold) is an attractive area to begin industrial lunar settlement. It is by far the closest mare basalt plain to either polar region, and its long 120° East-West stretch would allow electric power transmission that would provide any settlement with a greater percentage of month-around effective solar power than that enjoyed by the South Pole Shakeron rim location.

The nearest craters large enough and far enough poleward to have ice deposits are only 200 miles to the north. There is nothing like this near the south pole.

To the point of the article, Mare Frigoris has access to the rest of the nearside "mare-plex" in three

locations: far to the west through Sinus Roris (Bay of Dew) into Oceanus Procellarum (Ocean of Storms) and points south; (2) far to the East via Lacus Mortis (Lake of Death) and Lacus Somniorum (Lake of Dreams) into Mare Serenitatis (Sea of Serenity) and points south; and (3) in the middle via Valles Alpibus (Alpine Valley) into Mare Imbrium (Sea of Rains) and points south.

A southern gambit enjoying bandwagon status currently, will almost certainly prove to be a dead end. But if a commercial-civilian effort tries again here in the north, where all the assets are in place, the Alpine Valley is as sure to draw traffic as does the Panama Canal. The issue becomes one of how do we transform this awesome and unique lunar geological feature into a transportation corridor and still preserve its scenic beauty and scientific interest.

Railroads have a much smaller footprint than do highways, especially along stretches where no commercial development is allowed. Now that doesn't mean that there could not be a stop here and there for a tourist concession. At such locations there could be a hostel for hikers, or merely a pickup stop for a tourist off-road coach that would take people up to the valley crest hotel.

There could be a hiking trail along the ridge tops to either side, a trail both for hikers and small off-road vehicles. Another option would be a ridge top cableway along which tourists would have a superior vantage point from which to enjoy the sights along this 101 mile (166 km) lava-flow filled trench through the lunar Alps.

This writer is strongly in favor of putting in place a system of Lunar National Scenic and Geological Parks, and protocols for respecting them plus rules for granting tourist and mining concessions (only if the material to be mined is not present anywhere else) before lunar development commences. Many people point out that we need a new Moon Treaty that sets out the rules under which lunar development can begin, and private property rights be legitimized. We believe that this sort of set-aside system that ensures that lunar development will respect the Moon's natural beauty should be part of that Treaty. Such provisions, will help, rather than hinder future lunar tourism by identifying and calling attention to the Moon's greatest and most unique scenic and/or geological treasures.

A system of Lunar National Scenic Parks, even prior to our return, would get across to the public here at home, that the Moon is part of a Greater Earth-Moon human ecosphere, and that we intend to pioneer it with respect. Of course, that means a civilian regime, not the multi-national corporations, must be at the helm.

In general, we need to combat the pervasive popular suspicion that we are going to trash the Moon just as we are increasingly trashing the Earth. We need to get across that this will be a new beginning, and why the only way we can be successful on the Moon, is by starting off on the right foot, learning to live in harmony with our new host world. Indeed, there are powerful economic incentives for doing so. Externalizing costs the way we do here, (because we have so many pockets of underpaid labor) just would not work there. But that's another article and we have already talked about many related lunar environmental issues previously.

Anyone want to get a Lunar National Parks Group going? kokhmmm@aol.com <MMM>

Why Lunan Pioneers will turn their Gray World into a “Green” Sanctuary

By Peter Kokh

The common stock answer given by space enthusiasts to those who protest plans to go to the Moon by saying that “we will only trash the Moon *as we have been doing Earth* from time immemorial” is “the Moon has no biosphere, atmosphere, or hydrosphere to pollute.” This reply is anything but convincing. “Trashing” includes garbage piles, physical scarring, and other ways we disrespect *our own* environment. Again, we do what we do, postponing lifetime costs, because it is cheaper, and above all, because our terrestrial environment is so vast that we believe we can continue to get away with it.

Primates cannot be housebroken. And up till now, all the evidence has been that humans cannot be planet-broken. We foul our own home world.

The message we need to get across to the environmentally concerned is this:

“On the Moon, we must live in mini-biospheres of our own creation and maintenance and will be essentially living downwind and downstream of our selves. There will be no “somebody else’s backyard.” We will have to learn how to live in harmony with and within our pockets of Nature, or, in gamers’ language, it will be quickly “game over!”

We could learn those same lessons here on Earth, *but we won’t*, because the need does not seem pressing. But lessons learned and technologies developed on the Moon *because pioneers will have no choice*, can all be exported to Earth. In short, one very vital reason to go to the Moon, a reason seldom considered, is that we need to do so to learn how to save Mother Earth, not from energy shortages (that too) but “from ourselves.”

Yes, the Greens (I am one, and I am sure that some of you are also) are trying, and *have* come up with many ways for us to do better. Yet much of such insight is lost on those who do not see the urgency, or do not want to be inconvenienced, or do not want to see their incomes go down even temporarily. Environmental action on Earth helps postpone the day of final reckoning. But it cannot stop pillage of our planet simply because runaway population growth more than neutralizes these efforts.

Itemizing concerns and measures to meet them

Many people do not want to see the surface of the Moon, *as visible from Earth*, scarred. We need to stress reasons why a growing human presence on the Moon need not do so. Most mining will be within the already pulverized rock powder blanket 2–10 meters thick that covers the Moon. We extract what we need and leave the remnant in place. We will obliterate small craterlet dimples, but steer around bigger ones still too small to be seen from Earth even with most telescopes.

As to roads and railroads, they will themselves be too small to be seen by the naked eye. As to settlements, the need to cover them with regolith shielding, both to protect from the inclemencies of cosmic weather and to sustain a thermally moderate environment, will, so to speak, *camouflage them with moondust*. As to lunar city lights, light aimed upward will be wasted energy. Lunar cities, except for lit spaceports, will be nothing so dramatic as the brilliant urban cluster lights of Earth. Gradual oxidation of iron fines in the regolith will slowly redden the moondust, but perhaps in a way too subtle to

be noticed by the naked eye (as opposed to scientific instruments.)

As we pointed out in the editorial above (page 2b) lunar settlers will be behind the economic “eight-ball” for some time. Using energy and materials as efficiently as possible will be a must if they are ever to reach economic viability and sustainability. This need will force recycling of used energy and used materials at a level far beyond the token and and somewhat trivial measures we are slowly trying to adopt here at home.

We also need to identify what we waste so readily here on Earth: paper, wood, plastics: their constituents, carbon, oxygen, hydrogen, and lesser amounts of other volatiles are superabundant here on Earth: in a word, “dirt cheap.” Those same elements, excepting oxygen, are many orders of magnitude less abundant on the Moon and thus as precious on the Moon as are gold, silver, and platinum here on Earth. The very things we discard without a thought or care here below, will be religiously recycled back into our life-sustaining mini-biospheres. It will not be an exaggeration to say that this turnabout will be a matter of “life *or* death.”

Modern industry has learned a very neat but also nasty trick: using super-adhesives to assemble unlike materials that effectively cross-contaminate each other in a way that makes recycling impossible or many times more expensive than it needs to be. At the same time, the growing mobility of our population has created a niche for “knock-down” furniture that can easily be taken apart and reassembled at a new location. This method of assembly minimizes cross contamination and maximizes the possibility of proper recycling. *It should be the law.* The point is that options exist that will help Lunan pioneers avoid the pitfalls into which we have leapt.

Even on the Moon, with sunshine abundant enough to cover energy needs, nightspan as well as dayspan, it will make no sense to waste energy. For one thing, wasted energy exacerbates the need to radiate excess heat produced. Wasted energy also increases the mass of energy production equipment needed. Learning to reuse spent energy, by recycling everything possible, over and over again to reduce overall throughput, can but help the pioneers reach and maintain economic viability.

A lesson that many a detractor of environmental approaches has failed to learn or admit, is that doing things the right way generates more income opportunities than it removes from the approved list. All communities that have been “going green” have experienced economic growth, as counter-intuitive as that may seem.

Many space enthusiasts envision communities beyond Earth as inanimate constructs, clean and metallic, “uncontaminated” by vegetation or critters, even of the microbial kind. A few house plants will be “tolerated.” I suppose we can eat SoyLent Green or nutrition capsules produced by nanotechnology. Fortunately, these are the fringe in our pro-space constituency. Lunans will be surrounded by more vegetation than most urban terrestrial. We have to stop thinking, *and speaking*, of humans going to the Moon and Mars. We need to start thinking, *and speaking*, of Earth Life, *stewarded by humans*, bringing Mother Earth to Father Sky for the ultimate consummation. In that light, we will not be invaders, but suitors that can alone realize the previously thwarted ability of alien and sterile worlds to become life-sustaining worlds. In that light, we hardly trash them. We go to make other worlds “whole!” – PK

SHADOW PIONEERS

By Peter Kokh

*You won't have to move to the Moon
To become a Lunar Pioneer!*

Until the lunar domestic economy is so well established that most products needed for consumption are produced locally, and until the settlements are producing enough exports to pay for what they must still import, the “wages” of lunar pioneers will be counted in terrestrial monetary units, as “astronomical” - e.g. \$100,000 per hour.

The best way to bring that figure down to size in the interim, will be to reserve for pioneers on location, what only someone on site can do. Conversely, a partnering crew on Earth, paid more down-to-Earth wages and salaries, will strive to push the limits of teleoperation and telepresence as far as possible so that the lion's share of routine chores on the Moon, including the lion's share of the most dangerous chores, will be done by machines under their control, with on site supervision.

Even in the Apollo days, mission crews on Earth magnified the efforts of the six pairs of moonwalkers, by monitoring their activities, analyzing problems and glitches, and brainstorming ways to survive unexpected emergencies. Having mockups on Earth of equipment on the Moon helped considerably, notably in getting the Apollo 13 crew home safely, against considerable odds.

It would not be misleading to say that the actual number of people on the Moon during each of those missions, counting virtual presence on a par with actual presence, was considerably larger than two! In that respect, these “shadow pioneers” have been somewhat underappreciated. To say that the moonwalker duos stood on the shoulders of large teams on Earth would be an understatement.

This ratio of shadow pioneers to on site pioneers will continue, if not grow much larger and more varied in type of support offered, as we return to the Moon to set up a quasi-permanent hostel that can be revisited and eventually “built out” to a more fully functional size, as the seed of a first settlement.

In time, the first lunar settlement historians will recognize Earth-bound shadow pioneers as true Lunan pioneers. Those who go to the Moon and stay, and in time raise families there, will be just the frontline of a much greater population that should be revered as pioneers as well.

Many ways to help

Equipment operators

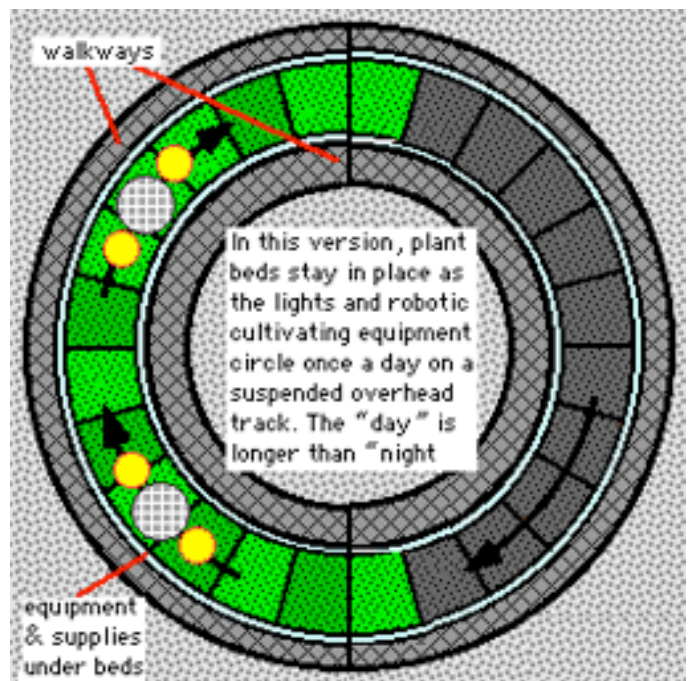
Perhaps a considerable portion of road construction, site preparation, and mining chores can be done remotely by teleoperators on Earth. The less than 3 second time delay in sensing a response to one's moves takes some getting used to, and some will master the trick much better than others. Indeed, if there was a legitimate place for child labor (*without* the long hours and low pay) this might be it. Young people have much more manual dexterity than adults, can more quickly and more easily master the game of anticipation needed to handle that time delay. To be fair, adults with a long

history of electronic game playing going back to their youths, will score well to. It will help that in the kind of regolith-moving operations listed above, we can afford the slower pace of operating under the conditions of that time delay.

Agricultural Chores

Given an automation-friendly design, such as the torus-shaped greenhouse layout sketched below, where cultivating equipment circles around and around at any pace desired, much of that equipment could be robotic. But supervisory intervention from Earth could make any such system even more efficient, clearing jams, repairing or replacing components, etc. Yet the on location supervision needed should be minor.

By contrast, one of the badly designed aspects of the original Biosphere II experiment was that the 8 biosphereians had to spend most of their waking hours nurturing crops to harvest, without much time for anything else, much less time for recreation. Even so, they still all lost weight, manifesting all the signs of malnourishment. On the Moon, we need to avoid such labor intensive operations. It will be more important to reserve actual on location manpower in the production of products for export. Exports, to facilities and installations in GEO and LEO and other in-space markets, as well as to Earth's surface, will bring home the lunar bacon.



Teaching, tutoring, advanced education

Long before the arrival of the first native-born lunans, settler-pioneers will need to be continually upgrading their education, as needs evolve, and methods change. It will be far more efficient in the early years, to have the teachers, tutors, and trainers on Earth. A person on Earth can be supported (food, health, etc.) much more cheaply than individuals on the Moon, in the early years.

In time, as the settlements evolve with an ever growing portion of both youngsters and seniors, these things will change. Older people needing to slow down physically, may take on ever more educational duties. If Lunans retire to “half-time” instead of 100% free time, they could take on the lions share of parenting opera-

tions to free young parents for export-production chores. We already see, though for different reasons, the growing percentage of "grandparents raising grandchildren." In the case of the lunar settlers, this will develop not as a result of more parents coming under the influence of drugs, etc. that for just plain economic sense. But we can expect that a significant amount of educating and tutoring will still be by telepresence, with on location assistants handling questions and problems.

Healthcare, nursing, medicine in general

This is one area where a high portion of work will be done by those on location. At the same time, ever more of diagnostic tasks will be done by computers. Interviewing patients, and channeling them to the right departments and many other preparatory work chores, can be more efficiently done by tele-presence.

Recycling

Sorting recyclable materials into the proper bins can be done by machines. Disassembly of products comprised of materials that need to be recycled separately is an area where computerized equipment can relieve a lot of people for other assignments. This presumes that all products will be assembled in a disassembly-friendly way (not with super bonding adhesives that lead to cross-contamination of dissimilar materials, a method that is "in" today.) Recycling equipment can be monitored from Earth, with a minimum of personnel on location on the Moon ready to intervene when needed.

Research and Development Facilities

When the mass of material being analyzed or used for experimentation is minor in comparison to the equipment needed, it will be cheaper to ship sample material "down the gravity well" to Earthside or orbiting facilities than to send all that equipment to the Moon. That may be the case early on, but as the population on the Moon grows, it will make more sense to do such research on location.

Field work: science and prospecting

It would seem to make sense that robotic or tele-operated equipment did the bulk of the scouting chores, while humans on location gave their attention to samples identified by the robotic equipment or terrestrial tele-operators as deserving special investigation. The final filter in what is significant and needs to be investigated further, is the human one. Artificial intelligence will probably always have its blind spots.

Other tasks done by people operating in settings less expensive to support

Automated stations would monitor the Sun for signs of approaching sunspots, flares, and coronal mass ejections. Humans on Earth would make the final judgments and alert pioneers on the Moon to take any special measures needed.

One could cite many more examples. The message here is that when some supporting task can be done on Earth without significant clumsiness due to the three second time delay, it will make economic sense to apportion tasks in that manner.

Many people on Earth will be involved in supporting roles in the epic drama of lunar settlement. To many of them, their contribution may be "just a job," and they'd prefer collecting a pay check to accolades. But if Lunar pioneers are to be honest with themselves, they

will be forever grateful to these cadres of assorted stay-at-home shadow pioneers.

Beyond the Moon

Will there be a similar Earthbound support group for the first waves of Martian Pioneers? Maybe, maybe not. Unlike the Moon which orbits the Earth in a fairly circular orbit, Mars and Earth both orbit the Sun each in their own orbits, with the distance between them varying from as little as 35,000,000 miles (140 times the Earth-Moon distance) to as much as 248,000,000 miles (a thousand times farther than the Moon.) As a result, the communications loop between the two planets varies from about 6 minutes to about 40 minutes - quite a bit longer than the less than 3 seconds separation between Moon and Earth.

We can teleoperate on Mars, but it is an excruciatingly slow process. If Mars was as close as the Moon, we could have driven Spirit and Opportunity over the same paths in weeks as opposed to years. So basically, we cannot really have the same kind of homeplanet - frontier teamwork as we expect to have on the Moon.

However, there is a way. If we were to set up logistical forward camps on Phobos and or on Deimos, crews there could teleoperate whole armies of small exploratory and prospecting probes in a relatively short time. Of course, such advance location crews would be vastly more expensive to maintain than the shadow pioneer crews on Earth.

This is a drawback and major impediment that confronts those who would settle Mars, that the more impatient Mars advocates (e.g. Robert Zubrin) want to push under the rug, if they consider it at all.

You can sum it up in three words: the Moon will develop a pioneer economy much faster than Mars, even though the latter world is blessed with more resources, because the Moon has the three most significant resources of all: "Location, location, location." The Moon can be settled at the end of an umbilical cord. Not Mars.

Mars will need to a different plan, a mass assault by a very large and diversified contingent so that we have as many people on the ground as soon as possible. And with no possibility of umbilical cordlike resupply or rescue, they would have to bring with them along with a yolk sac of resources and supplies.

The unworkably long communications lags, and the very infrequent launch windows, 25+ months apart (vs. virtually anytime for the Moon), will require an all out effort right from the start, with little in the way of realistic exports worth the transport cost back to Earth for income. Solar Sail freighters can blow away the infrequency obstacle and luxurious cycling spaceships will make enjoyable the very long journeys either way. At ISDC 1994 in Toronto, this writer warned that despite all Mars' many plusses, all attempts to develop an economic case for Mars (Zubrin's rare gems, and special pharmaceuticals growing in Mars soil) are grasping at imaginary straws. A case can be made, but only by developing Mars and the Moon apace with three way trade. But we drift from our topic.

While many want in their impatience to bypass little Phobos and Deimos, they only cut their own throats. Patience pays off. Impatience usually backfires. Developing Phobos and Deimos in synch with the development of Mars surface settlements is the only

rational plan. But irregardless of how those frontiers are opened, there will not be the same amount or scale of significant shadow pioneer contributions.

Productivity costs are not the only consideration

Safety is important also, and even further into the frontier future, when, as the lunar domestic economy grows to the point where labor costs are a lunar domestic matter and comparison with terrestrial labor costs have become meaningless, we will still be employing a high ratio of automated robotic and teleoperated devices on the Moon, for safety reasons.

NASA's experience with EVA (Extra Vehicular Activities), i.e. showed activities by personnel wearing spacesuits incur significant safety and fatigue risks. Mistakes that on Earth would be easy to dismiss in space and in vacuum in general, can easily become fatal or life-threatening. We will always want to minimize the number of suited individuals doing field- work of various kinds. There will be a difference, of course. Teleoperation will then be done locally, by pioneers inside pressurized environments, at whatever distance, without felt time delays.

Safety is not the only challenge. If we do not succeed in developing space/pressure suits that are more user-friendly, fatigue which is a definite factor in EVAs at the International Space Station, will continue to be an issue on the Moon. NASA and several contractors had been working on alternative suit designs, but funding for this work has been cut. Unfunded research continues at a low priority pace.

Will "Shadow Pioneers" appreciate their role?

It has been said that only 15% of people are fortunate enough to get paid for doing something that they really love to do. The other 85% do what they do because they have to earn money somehow. "It's just a job!" Undoubtedly, to many "shadow pioneers" their work will indeed be just another job, and many will care less how much their work may be appreciated by on location lunar pioneers. But in fact, it will not just another job, and we predict that the ratio of personnel involve who get extra satisfaction from the realization of how important their work is, will be on the high side.

Pioneers on the lunar frontier, however, may well better appreciate the efforts of shadow pioneers. Indeed, it would not be surprising if future frontier calendars listed a "Shadow Pioneer Day" with possible holiday status. So why don't we in America have a day of appreciation for all the pioneers who helped lay the foundations for the freedom and prosperity we all enjoy? Maybe that is a separate issue to pursue.

Conclusion

Teleoperation and telepresence will play significant roles in the opening of the lunar frontier and the spread of a global human presence there. On Mars they could play a role, but a less important one. After the Moon, the most promise lies in teleoperating equipment landed on Earth-approaching asteroids.

Teleoperators will be shadow pioneers, doing invaluable service. They will allow fewer people actually on the Moon to get more work done at less cost, and just as importantly, at less risk. They will be true lunar pioneers, even though they may remain out of the public eye. But if the frontier effort is successful in establishing a viable Earth-Moon economy, their work should be long remembered.

<MMM>

Article Sequel: A Similar Problem

The Limits of Delayed Conversational Response

By Peter Kokh

We ran an article about the limits to effective time delay conversation in MMM #131, Dec 1999, p. 6

"**The Colloquipause***: the end of conversational space."

[Reprinted in MMM Classic #14, pp. 4-6, a free download from www.moonsociety.org/publications/mmm_classics/ or from www.lunar-reclamation.org/mmm_classics/

[* "colloquipause": the distance over which *fluent* conversation becomes *impractical* - *our coinage & definition*]

In this article, we called for a pair of simulation exercises: one series would start with the Moon's three second delay and gradually lengthen it, until most experimenters became weary or frustrated with the growing length of the time delay.

" "At some point individual speakers will, upon receiving the response, start having trouble remembering what they said to which the reply is a response. Different people have different attention spans, and differing susceptibilities to distraction. The point is to find at what level of delay each person says 'enough! this no longer feels like conversation!'"

In the other series, volunteers would experiment teleoperating using the 40 minute time delay, gradually shortening until they reached a point where it seemed to become manageable, started to feel "live." It would be interesting to see how far apart the maximum tolerable and minimum tolerable time delays might be for the two crews. We don't really have any idea!

Not Quite the Same Game

But is this relevant to teleoperation? **Delayed conversational response is not the same as delayed teleoperation feedback.** We need to do a similar set of tests, not with conversation, but with teleoperation using increasing/decreasing physical feedback delay times.

Such experiments could let us know what the practical range is for teleoperating equipment on an Earth-approaching asteroid. 500,000 miles? 3,000,000 miles? The equipment cost involved would not be great. Experiments aimed at determining the practicality of teleoperating equipment on the Moon have already been done using Radio Shack toy cars with a programmed 3-second time delay for joystick feedback. A Moon Society or NSS chapter or a school class could undertake the experiment.

To give this research validity, such experiments should be tried by several groups to identify a mean figure and a +/- variance. Thus a common report center must be identified. If there is substantial variance, we need to find out what was special about the group or groups that did best.

Of course, trying to teleoperate machinery that can do a variety of chores will require more than a simple joystick, as well as more than just manual reflexes. In fact, we do not know what the limits are to the kinds of chores that can be effectively teleoperated. **Pushing the limits of teleoperation could be a major focus for a future Lunar Analog Research Station.**

While this research seems rudimentary and low level, the results could be of major importance. <MMM>

MAINSTREAM SPACE

By Madhu Thangavelu <thangavelu-girardey@cox.net>

It is now more than 50 years since the dawn of the space age, and even today much of space activity remains the monopoly of governments and their sensitive defense establishments. Space exploration budgets are closely tied to defense and intelligence pursuits, and are all linked in some way, shape or form. Indeed, it is correct to say that space activity is a niche human endeavor and not yet fully integrated into the mainstream of peaceful, sustainable, progressive human activities.

Commerce, the lifeblood of modern civilization and a chief agent of transformation, continually creates, evolves and sustains mainstream activities. Transportation infrastructures, housing, factories, and manufacturing and energy production and distribution are clearly mainstream activities. The recent proliferation of Internet technology and associated business developments, which continue to spur its growth at a stunning pace in arenas as diverse as education, telemedicine and gaming, make it an ubiquitous and mainstream activity.

Energy production and distribution, with the petro-leum industry playing a significant role, is a mainstream activity. While the media these days tends to highlight our addiction to fossil fuels and its effects on the biosphere, we rarely pay attention to the fact that petroleum by-product utilization, like polymer technology, have entered the mainstream and become an integral part of daily life for all of modern civilization.

Space exploration programs, both manned and robotic, are not mainstream activities. The allotted budgets for space exploration across the entire world pales in comparison to the resources oil companies bring to bear just for prospecting – exploring for new oil fields.

However, even while shackled to national security, space activity has managed to grow roots into modern society and continues to engage our noblest aspirations and uplift the human spirit.

A ringing success story of space entering the mainstream is telecommunications. Ten years after the birth of the space age, satellites were beaming TV pictures around the world and people were watching Neil Armstrong and Buzz Aldrin set foot on the Moon. Twenty years later, geosynchronous communications networks made the world smaller by hooking up the financial and commerce hubs of the world and transporting data in ways and rates that terrestrial systems find hard to compete with, even in the age of the Internet and surplus dark fiber. Space telecommunications is now a sturdy and lucrative industry, which is constantly evolving to meet the needs of the mainstream customer in the world of commerce and media while supporting the all-around needs of the defense establishment as well.

What are the other areas of mainstream human pursuits where space can play a significant role? The production of clean, environmentally friendly power from solar energy in space and its transmission and distribution globally could be a very lucrative industry. Such a vision was first proposed in the 1960s, and after many iterations and reincarnations at various think tanks and conferences, it now again is becoming a strategic interest of both our nation and all the exponentially growing economies around the world.

Wireless transmission of energy, also known as power beaming, has inherent implications for environmental modification as well. This nascent technology,

which would allow us to control weather by design to ameliorate the effects of hurricanes and precipitation that cause deluges and droughts, could become a beneficial offshoot of space-based energy production. Power beaming, when trained outwards into space also could provide energy for spacecraft. Some concepts even propose using such beams to mitigate rogue asteroids that might endanger Earth.

Transportation is a vital infrastructure where the need is growing, ratcheting up the technologies for quicker access to the various metropolitan cities all over the world. Los Angeles, New York, London, Paris and Frankfurt now compete on equal footing with Shanghai, Dubai, Mumbai, Singapore and Tokyo. In this flat world model, quick, efficient worldwide transportation plays an even more crucial role. Transatmospheric vehicles, based on crafts like the space shuttle, could usher us into a new era in mainstream global transportation.

If space activity can do for energy production, power distribution (with potential for environment modification technologies) and transport infrastructure in the next three decades what it did for telecommunications in the last three, the ramifications for modern society are truly staggering. Cheap and clean power in space and on Earth, and the ability to move goods and people swiftly around the world in a fraction of the time that it takes today, would make the world smaller and perhaps a much more tightly knit community.

The emerging private space companies, with little or no government support, are helping to mainstream space. Virgin Galactic and Burt Rutan's SpaceShip series are quite close to carrying people to the edge of space while ground support infrastructure is being created in parallel. Bigelow Aerospace, with hard data trickling down from test articles in orbit now, is getting ready to commission its luxury hotels. Teaming with SpaceDev, Bigelow also is planning tourist missions to the lunar surface. The Falcon series of launchers by Space Exploration Technologies Corp. will soon bring competitive pricing to the market. The X Prize Foundation, which successfully administered the first completely private suborbital spaceflight, now has teamed with Google Inc. to offer a prize for the first nongovernmental lunar surface mission. Other companies are working on spacesuits and related products and some have their eyes on the Moon, asteroids and beyond.

All these activities will contribute to a progressive and self-sustaining industry, catering to a wide range of economic interests. Just as the petroleum industry and the Internet now pervade every aspect of mainstream society, the space industry has the potential to transform modern civilization.

While many of us are wary of actions that might lead to an arms race in the orbital regime and weapons in space, the leaders of nations also know that space activity is the ultimate international arena for collaboration. When commerce between nations grows, so do bonds, and history tells us that goodwill and peace dividends follow. There is no doubt in my mind that mainstream space activity holds the key for a peaceful and vibrant, pluralistic and multicultural modern civilization in this 21st century.

Madhu Thangavelu conducts the Graduate Space Concepts Studio in the Department of Astronautics and School of Architecture at USC, and is co-author of "The Moon: Resources, Future Development and Settlement."

Zubrin's Challenge: "it takes more fuel to land on the Moon than it does on Mars" – *Maybe, but we can cheat too!*

By Peter Kokh

Let's begin by admitting that I am not a "rocket scientist!" Not even close. One glance through the topic's I've written about over the years in MMM, will show that I am more interested in what we can and will do "once we get there" than in "how we will get there."

But I can spot a flaw in an argument a mile away. Zubrin's case is that since Mars has an atmosphere, a spacecraft can use balloons or aerobrakes to save fuel on coming in for a landing. Quite true. However, only an aerobrake will be effective in shedding most of the craft's momentum. And here is what he doesn't tell us.

- (1) Because of Mars substantially deeper gravity well, an incoming craft will build up more momentum that needs to be shed.
- (2) An aerobrake will add to the craft's weight and require both more fuel to set out from Earth to Mars (which will require more fuel than needed to set it on a translunar trajectory even without an aerobrake!)

Now we will not put numbers on those penalties, but it is enough to show that those penalties exist. That said, we admit that there may still be some advantage, although much less if any at all. We want to talk about what devices spacecraft bound for the Moon, where an aerobraked descent is out of the question, can use to bring down the fuel cost of landing, narrowing the cost of landing gap between destination Moon and destination Mars, if not eliminating it altogether.

Taking along landing fuel, but not the oxydizer

In a cryogenic system, using liquid hydrogen fuel and liquid oxygen oxydizer, the oxygen weighs eight times as much as the hydrogen, even though the liquid hydrogen tank is the more massive. With other liquid fuels, the fuel tank need not be so big because the fuels will be more dense. But the oxygen is likely to still be the weightier component. What if we could do without it?

Beam-powered propulsion

http://en.wikipedia.org/wiki/Beam-powered_propulsion

"**Beam-powered propulsion** is a class of space-craft propulsion mechanisms that use energy beamed to the spacecraft from a remote power plant. Most designs are rocket engines where the energy is provided by the beam, and is used to superheat propellant that then provides propulsion, although some obtain propulsion directly from light pressure acting on a light sail structure."

This is no more cheating than the use of an aerobrake. Both are appropriately applied ingenuity! Either microwaves or laser beams could be used for this purpose, but I suspect, given the relatively small area of the propellant-containing bell, a laser beam would be by far the better choice. Now what various fuels would work for this application are not something we are prepared to talk about.

To be fair with our fellow Mars enthusiasts, we admit that the Mars aerobrake can land anywhere, the lunar ablative ferry can only land at laser beam locations, i.e. at properly-outfitted spaceports.

Other ways to use less fuel in landing on the Moon "Crashportation"

In the late 1980s, Chicago inventor Ed Marwick put forth an elaborate proposal in which guided payloads enter a sloping chute dug into the surface and encounter ever denser sprays of regolith dust, slowing the capsule down to a halt. Such a facility would have to be as long as a mass driver per level of Gs to be tolerated. I doubt if this scheme would work.

"Harenodynamics"

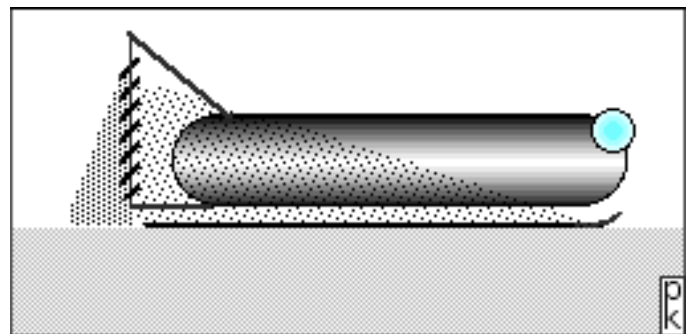
Famed rocket scientist, **Krafft A. Ehricke**, in his paper "Lunar Industrialization and Development – Birth of Polyglobal Civilization, included in Lunar Bases and Space Activities of the 21st Century, W. W. Mendell, Editor, Lunar & Planetary Institute, Houston, © 1985, pp. 828–55, wrote (pp. 848–850) about his concept of a **Lunar Slide Lander**. Most of the velocity an incoming craft needs to shed is horizontal velocity relative to the lunar surface. Ehricke proposed an 80 km (50 mile) landing strip. The surface would be raked free of boulders and stone to a depth of 20–50 cm (8–20 inches) leaving just compacted moondust. The Slide Lander could touch down at velocities as high as 5500 km/hr (3,400 mi/hr) gradually transferring its momentum to the landing strip over the 80 kilometer stretch. The slide or skids would have to bear up under considerable heat from friction. But Ehricke thinks this is a doable engineering challenge.

Now on Mars, you couldn't land at such speeds even though the atmosphere is very thin. In the cited paper, Ehricke does not offer an illustration of the slide lander, but only of the runway sweeper. Ehricke called his concept *harenodynamics* [from Latin harena = sandy.]

By the way, if you do not have this hefty volume, you owe it to yourself to add it to your library. It is the classic, and even 23 years after its publication, it is full of valuable information, concepts, and inspiration.

"Harenobraking"

In the May 1992 issue of MMM #55, fellow Lunar Reclamation Society (NSS–Milwaukee) member Doug Armstrong and I published a short article on the subject under the title "Enhanced Harenabraking."



In the crude illustration above, the incoming craft kicks up a spray of moon dust upon making surface contact on a prepared runway. The dust hits breaking louvers to the rear and falls back to the surface, its energy spent, as the craft continues to slow down. Even if this method is practical only below a thousand km/hr, it would help save retro-rocket fuel. Making this real is a matter of exploring engineering options and suitable materials. Readers are welcome to come up with their answers to Zubrin's Challenge. Send your ideas, and illustrations, to MMM, c/o kokhmmm@aol.com

The Mars advantage does not hold up! <MMM

Our “Environment” includes more than Earth

In this month’s In Focus Editorial (pp. 1–2) and feature Essay (pp. 7–9), we argue that the Solar System and even the Universe at large, are parts of the total environment within which humanity has arisen, and without which any philosophy of the destiny and vocation of humankind cannot but be inadequate and stunted.

This may come as a jolt to the average Joe or Joan for whom “The World” is basically our home planet plus window dressing points of light in the day/night sky.

IN FOCUS  Taking the Lead in the Holistic Environmental Movement

“Oh no, complicating discussion by adding in a new term!” Sometimes it is necessary. Environmentalists, despite the sincerity of their passion, and the apparent soundness of their philosophy, have produced a very one-sided movement. It *is* one-sided, because the context of the rise of humanity includes more than our home planet, Earth. We could not be, Earth itself could not be, what we are without the larger cosmic context. And taking that meta-context into consideration vastly expands environmental “caretaking.”

Humanity’s and Earth Life’s (Gaia’s) environment is in fact dual. It is a matter of both Mother Earth and Father Sky. We are equally children of the Universe at large as pointed out in our feature essay, pp. 7–8 this issue. Sadly, the integral cosmic component of our environment is all but totally ignored by environmentalists.

But we space enthusiasts ourselves fail to realize how radically pro-environment our own goals are, and in that failure, we contribute to the mutual hostility of the two groups. As we bring into focus in our “Human Expansion Triway into Space” presentation, www.moonsociety.org/spreadtheword/ppt/Triway1.ppt

In this presentation, we show how those focused on asteroids want to preserve our planet from the threat of killer impacts; how those focused on the Moon want to tap lunar resources to help us tackle our intertwined environmental degradation / energy shortage problems; how those focused on Mars want to create a “just-in-case” “second basket” for Humanity’s and Gaia’s “eggs.”

The Moon Society and the National Space Society, working as a team, put together a conference proposal tasked with beginning a “conversation” between space solar power advocates and environmentalists. Presented to the EPA for funding, we did not make the first cut. We may try again, but it is worth doing on our own, if need be. But sadly, not all space enthusiasts seek to combine forces with the environmental movement. Many of us, especially politically conservatives, see the environmentalist as the “enemy” rather than a natural ally. Yes, “they” are hostile to us! But to match hostility with hostility is not only self-defeating, it is childish. We must take the lead in bringing the two sides together. We must realize that we ourselves are environmentalists who treasure Mother Earth. And our own divergent focus points show that as we have just stated. We can better see both sides.

But we have apologies to make. The hostility of environmentalists to us is not without cause; we are blinded to a situational fact of life! To be truthful, given the long lead time for SBSP, it is both dishonest, foolish,

and counter-productive in a manner that courts global suicide not to lend our support to shorter lead time, local and community based efforts to diminish and contain the problems, on a one-on-one basis.

If we spurn environmentalist efforts to promote wind and ground-based solar, and other cleaner energy solutions as “inadequate,” we lose significant opportunities to buy Earth time, while we are continuing our efforts to bring space bases solar power technologies to a near-term readiness state. We cannot afford to do nothing while waiting 10–20 years for SPS *to begin to come online!* That would be cutting off our nose to spite our face. It would be childish and immature.

Collectively, we need to quit posturing and instead to seize the leadership in **promoting a holistic version of environmentalism** that recognizes the duality of Mother Earth and Father Sky, and in that context, work side by side with traditional Mother Earth environmental groups for a better future for our children and grandchildren and for our descendants for generations to come as we spread beyond Earth to the Moon, Mars, the Solar System at large, and begin our pilgrimage back to the stars that begin it all. *“Of stardust we are, to the stars lest us return.”* Think holistic: Mother Earth & Father Sky. It’s not an either or proposition. It never has been. We must change our mindsets accordingly. **PK**

LUNAR ENTERPRISES AND DEVELOPMENT

Especially prepared for *Moon Miners Manifesto*.

© Philip R. Harris, 2009 – PhilHarris@aol.com

Installment 1

Dr. Harris is a Moon Society member, a management/space psychologist, and former NASA consultant and Faculty Fellow (www.drphilipharris.com) This is an excerpt from his 2009 book, *Space Enterprise – Living and Working Offworld* www.springer.com

EXHIBIT 1: Why the Moon?

“Of all the sites in the Solar System, the Moon is the most logical first place to establish a permanent off-world human settlement. Why? Because it is nearby, less than three days with existing propulsion technology. It has a wealth of resources that can be used to support a broad range of human activities from science and engineering to commerce and tourism. It has an abundant continuous, and virtually unlimited supply of solar energy. It offers the opportunity for a greatly expanded program of space exploration. It is within our technological reach!”

¹ David Schrunk, Burton Sharpe, Bonnie Cooper, Madhu Thankgavelu

After a hiatus of some forty years since humanity’s first lunar landing, we are now planning to return to the Moon permanently, hopefully by year 2020. No **united** vision, plan or strategy for exploring, settling, and industrializing the lunar surface has come forth from the world’s space agencies, despite numerous conferences, studies and reports on the subject. However, NASA has undertaken to implement a national space policy to do just that called, *Vision for Space Exploration*. The Agency is beginning to seek collaboration from public and

private entities within the global space community in this latest orbital venture.. But to build a lunar transportation system and outpost within a dozen years, requires planner to face harsh economic, technological, and political realities, leading to the realization that the only way **Earthkind** can afford this macroproject is by means of inter-national cooperation with major participation by private enterprise. If the limited resources of the China, Europe, India Japan, Russia and the U. S. A. were combined into joint tech-nological enterprise on the Moon, then synergistic activities there would encourage competing space constituencies to work together on lunar development. Exhibit 1 gives the principal reasons for doing this.

The Moon can serve as the best space station and launch pad to Mars and beyond. Space science proponents would then be able to use this lunar platform for their experi-ments, both in astronomy and life sciences, as well as to launch from there additional planetary missions. Simultane-ously, those favoring human exploration and “manned” missions might use the Moon as a laboratory for study of extreme environments and habitats, comparable to what is happening today among cooperating countries in Antarctica. In addition, champions of lunar industrialization could undertake research programs relating to manufacturing, mining helium-3, or energy transmission by power beaming, and other uses of *in situ* resources, such as lunar oxygen produced from ilmenite.²

The uniqueness of the Earth-Moon system provides an advantage for humanity to use this lunar laboratory to create a spacefaring civilization for the New Millennium! The Moon’s characteristics as a resource to humanity are illustrated next in Exhibit 2. The Moon is an enormous piece of accessible real estate, comparable to the largest continent on Earth. As meteorites struck the lunar surface, they shattered solid rock which mixed with the soil creating **regolith**, a fine powder or cosmic dust which can be from three to sixty feet in depth. Apparently, it also contains a lot of oxygen, so the prize will go to whomever can extract the oxygen most quickly. Regolith has other bounty to be obtained – hydrogen, carbon, nitrogen, potassium and other trace elements. When asteroids crashed into the Moon, there is a likelihood of deposits of platinum and other valuable metals.³ A key question, according to Dr. Paul Spudis, a planetary scientist at Johns Hopkins University, is whether the Moon’s resources can be used profitably.⁴ (For NASA video on *Regolith Challenge*, try online website: <http://one.revver.com/watch/292585> and 295790).

In 1969, humanity’s first lunar envoys installed a commemorative plaque with these words: *Here men from Planet Earth first set foot on the Moon. We came in peace for all mankind.* Then in December 1972, astronauts from the last *Apollo* mission fastened another plaque nearby on that original landing module: *Here man completed his first exploration of the Moon. May the spirit of peace in which we came be reflected in the lives of all mankind.* And within a dozen years, our species will return permanently to “Sister Moon,” so called by a 13th century visionary, Francis of Assisi! A great deal of the Earth’s character has been influenced by its relative close position to this Moon – it is responsible for two thirds of our ocean tides; its gravitational tug spins the axis of the Earth, causing our planet in wobble through a set of complex and majestic cycles. And in the course of

millions of years, its massive bulk prevents other celestial bodies and the sun from making Earth’s axis go through extreme changes like those of Mars. (Refer to Exhibit 2)

EXHIBIT 2: Characteristics of the Moon

Characteristics of the Moon

Radius	1740 km (0.3 x Earth’s radius)
Surface elevation	+7.5 km to -5.6 km
Mass	7x10 ²² kg (1.2% of Earth’s)
Gravitational acceleration	1.6 m/s ² (1/6th Earth’s gravity)
Lunar day	27.3 Earth days (sidereal period) 29.53 Earth days (sunrise-sunrise) (one side permanently facing Earth)
Surface temp.	+130° C at equator, local noon -200° C in permanently shadowed areas near the poles

Utilizing lunar resources is feasible, but the problem has been well summarized by Werner von Braun: ***We can lick gravity, but sometimes the paperwork is overwhelming!*** *Source: NASA.

For further information, contact the International Lunar Exploration Working Group through Dr David McKay at NASA/JSC – dmckay@snmail.jsc.nasa.gov

The Moon is our “beachhead” for exploring and settling our Solar System! The author presents here a near-term strategy for utilization of its resources for the benefit of our planet’s inhabitants. By turning outward in peaceful lunar development, the human family can develop both its potential and that of its offworld bounty!

1. RECLAIMING THE MOON: RATIONALE

As this is written, we are celebrating the 50th anniversary of *Sputnik*, a satellite that launched our Space Age. It is fitting that the global space community is again preparing to move beyond Earth and back to its sister Moon, possibly establishing in the process a twin-planet economy. Recently, the magazine of the National Space Society, *Ad Astra*, devoted a whole issue to “Reclaiming the Moon: The First Steps.”⁵

In these pages, space writers made a case as to why humanity should do this. Jeff Foust gave a recent review of US policy on returning to the Moon permanently, *Vision for Space Exploration*. That writer explained that NASA’s implemen-tation plan entitled *Global Exploration Strategy*, was developed with the participation of some 14 space agencies which iden-tified 180 potential objectives for lunar exploration, divided into 23 categories ranging from astronomy and lunar geology, to commercialization and technologies testing. Six exploration themes emerged for such endeavors – human civilization, scientific knowledge, exploration expertise, global partner-hips, economic expansion, and public engagement. Within that context, NASA then engaged in a *Lunar Architecture* study that favors the building of an international Moon base. Before 2020, a decision is to be made at to site for the first outpost – the current consensus is a location the lunar north or south pole. Some are for the Shackleton crater near the latter where the Sun hangs low on the horizon for most of the lunar day, thus enabling use of solar power both on the Moon, and possibly power beaming space-based energy

to the home planet in the future. Others are for a base near Malapert Mountain also near the South Pole because of similar sunlight advantage and direct view of the Earth.

Lunar scientists estimate that some 20 billion tons of ice may be present in permanently shadowed regions of craters near both poles. In early 2009 mission is planned for a *Lunar Reconnaissance Orbiter* to gather data confirming which is the best location to start a research outpost. Both international and private partners will help to determine the eventual size of this base, which I have called *Lunar World*.⁷

The current thinking is to start with crews of 4 to be rotated every six months until permanent occupants, dubbed *Selenians* [or *Lunans*], determine to stay longer. A versatile lunar lander, yet to be built, is critical for bringing humans, robots, and equipment to the lunar surface.

By 2013, the Agency hopes to have made decisions on this spacecraft, plus a heavy-lift launcher, possibly the *Ares 5* with the *Orion* as a crew exploration vehicle presently being now built by Lockheed-Martin. Significantly, this is all viewed as a long-term, evolutionary process.

In this same 2007 Spring issue of *Ad Astra*, Jeanna Bryner discussed the split in astronomer thinking on orbital telescopes, or one that is lunar-based. That year a series of meetings were inaugurate called,

“Astrophysics Enabled by Return to the Moon,” examined both alternatives, noting that lunar telescopes would benefit by the Moon’s lack of clouds or any blurring atmosphere erected on a permanent platform. The astronomers are attracted to the farside of the Moon which is free of radio pollution, but for which no base is yet planned for there. Thus it is more likely that a deep-field infrared observatory will be erected on the lunar South Pole where the necessary living, power, and communications infrastructure will exist in the near-term. An upright telescope could be built that has a 330-foot scope of the Moon that enables astronomers to view the galaxies in a way impossible on Earth. Semi-autonomous robots are expected to service the anticipated facility.

Again this same issue of *Ad Astra*, Andrew Chaikin wondered what it would be like soon for Earth’s inhabitants to look up on the Moon, knowing that people are actually living and working there. That writer sees the Moon as a spectacular world, a cosmic library full of secrets about our universe to be decoded. While NASA has the ability to turn our dreams into machines, Chaikin wants care in choosing dreams wisely that will take us down the path of becoming a *multiplanet* species, living out our DNA destiny! The Moon, then, is the stepping stone, a place to teach and prepare people for living in other worlds beyond their home planet!

There is so much to be learned in this big lunar laboratory - human-robotic relations, closed-loop recycling, telemedicine, tele-education, scientific, and technological innovations. Literally, a permanent, sustainable lunar settlement means changing human culture and species! Almost four decades ago, *The New York*

● Dr. Harris has written about the first industrial park on the Moon in *Launch Out - A Science-Based Novel About Space Enterprise, Lunar Industrialization, and Settlement* (www.buybooksontheweb.com)

Times did a special supplement on “The Moon as a New Frontier.” [6]

The feature opened with:

“A new age began when Man first steeped onto the Moon at 10:26 p.m. (Eastern daylight time) on July 20, 1969... The Moon is no longer merely a disembodied orb, a subject of myth, and abstraction in the sky. It has been touched and now is a place.”

Yes, a place for human exploration, some 238,860 miles from Earth on the average! In size, it is 1/4th that of Earth but in mass, 1/81st that of our planet. Its temperature daytime when the sun at its zenith, is 250 degrees Fahrenheit, while at night minus 250 degrees, The Moon spins at uniform speed, but orbits at variable speed, and its wobbles are called librations. This orbiting land mass, some 2,160 miles in diameter, is presently three days away from Earth. As the Moon revolves around the Earth, Earth revolves around the Sun.

Regarding its origin, there are three basic theories about our Moon - it broke away from the Earth; it was formed with our planet from a the same whirling cloud of dust, and other material, evolving with less density; it was formed elsewhere, passed near the Earth, was slowed down by debris, and captured by its gravity. The Moon’s multiple value to humanity extends from an object of study and a base for examining our universe, to a place for building laboratories, factories, and habitats (see exhibit 3). Others propose to utilize its raw materials, as well as to establish a refueling stop for launching spacecraft out into the Solar System. There are those who envision the lunar surface as a listening post for us to better decipher cosmic messages, from particles to subatomic objects.

The second man on the Moon, Buzz Aldrin, has long argued that the Moon could provide both rocket propellant and shielding for human structures, as well as supply of our space needs because of its weaker gravitational field (about one-sixth that of Earth). With an MIT doctorate, he would like to see a fleet of “space tugs” built to create “Trans-Lunar Rendezvous,” using the Moon as a refueling depot. No wonder Buzz Aldrin wrote a book for children - *Reaching for the Moon*, for it *will* be the generations of youth who will make the most of lunar opportunities.⁷

EXHIBIT 3: Lunar World?

One view of a 21st century lunar base, beginnings of a major industrial park, and settlement on the Moon.

*Source: artist rendering by Lockheed Missiles & Space Company, Inc., Sunnyvale, California, U.S.A.



As we prepare to return permanently to the lunar surface, author James Hansen reminds us that two-thirds of today's Earth population was not alive when the first humans visited the Moon.⁸ And only four of the six astronaut commanders who piloted a spacecraft down to a lunar landing are among the living. Of the twelve moonwalkers who had a great time there, nine are still with us, all in their 70's.

The implication is that earthkind needs a massive re-education as to the Moon and its potential. Further, this second time, we depend on the established technologies and memories of the Apollo missions legacy. Perhaps Harrison Schmitt, the last man on the Moon, put it best when he said: *that return will be comparable to the movement of our species out of Africa some 150,000 years ago....a return to the Moon today will be comparable to the permanent settlement of North America by European immigrants....Apollo was our evolutionary path to the future.*⁹ Schmitt, a former U. S. Senator from New Mexico, recently gave these reasons as to why we must go back to the Moon. They include (1) clean abundant energy; (2) stepping stone to Mars; (3) species survival; (4) expanding understanding of the universe; (5) save Earth from threats from space; (6) education in space exploration stimulates the mind in unique ways; (7) lunar tourism and settlement.

When the Doctors Buzz Aldrin and Harrison Schmitt met at a Lunar Base Symposium in Houston, TX (June 1999), they concurred with the event's organizer, Rick Tumlinson, founder of the Space Frontier Foundation, that going back to the Moon is a opportunity for a *new synergy between govern- ment and the private sector*. This time, Tumlinson believes the Moon is close enough to Earth for private enterprise to play a big role there, and to make it profitable. (The space between the two celestial bodies is called *cislunar*.) Just imagine if the peoples of this planet were to work together on this venture for the benefit of all!

"Ten Reasons to Put Humans back on the Moon" was the title of an online essay by science writer, Robert Roy Britt (www.space.com/moon, 12/8/03). In addition to the above motivations, he added these:

- Satisfy the soul by the exploration quest for new knowledge...
- Bring nations together in an offworld technological enterprise...
- Gather rocks from the "attic of the Earth" for further scientific analysis...
- Study catastrophe regarding asteroid impact to answer survival questions about our cosmic shooting gallery...
- Spur technology advances, including for health and economic benefits.

Finally a worldwide meeting of lunar experts in 2003 gathered for the fifth time, calling now for a sequence of technological, exploratory, and commercial joint missions that would culminate in establishment of a permanent human presence on the Moon. Further, these ILC/ILEWG conferees issued **The Hawaii Moon Declaration**, which underscore the importance of lunar development for humanity in the 21st century. These are the words of many representatives from spacefaring nations:¹⁰

The Moon is currently the focus off an international program of scientific investigation. Current missions underway or planned will lead to the future use of the Moon for science and commercial development, thereby multiplying opportu- nities for humanity in space and on Earth. We need the Moon for many reasons: to use its resources of materials and energy to provide for our future needs in space and on Earth, to establish a second reservoir of human culture in the event of a terrestrial catastrophe, and to study and understand the universe. The next step in human exploration beyond low Earth orbit is to the Moon, our closest celestial neighbor in the Solar System.

**REALTY CHECK: THE UNITED NATIONS
- OUTER SPACE TREATY**

The exploration and use of outer space, including the Moon and other celestial bodies, shall be carried out for the benefit and interest of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind.

Outer space, including the Moon and other celestial bodies, shall be free for exploration and use by all States without discrimination of any kind, on the basis of equality and in accordance with international law, and there shall be free access to all areas of celestial bodies. There shall be freedom of scientific investigation in outer space, including the Moon and other celestial bodies, and the States shall facilitate and encourage international cooperation in such investigation.

Article I, the United Nations 1967 Outer Space Treaty.

1.1. International Lunar Agreements and Initiatives
The legal context for any nation or consortium to carry out activities on the lunar surface is evident in the above United Nations' Outer Space Treaty of 1967 (refer back to chapter section 9.4). In December 1979, a second document was drafted entitled, *Agreement Governing the Activities of States on the Moon and Other Celestial Bodies*. Because of its anti-developmental provisions, many of the leading spacefaring nations, including the U.S.A. and the former U.S.S.R., did not sign this document prepared by the Committee on the Peaceful Uses of Outer Space (COPUOUS). Only nine nations, largely representing developing economies, signed that resolution, while five others had not yet ratified it. In 1984, this so-called treaty went into force after being ratified by only five nations. But in the summer of 1994, the Moon Treaty or Agreement came up for review in the United Nations General assembly, and within the U.S. State Department. In a private letter to the author (May 18, 1995), its chairman, Peter Hohenfellner, informed me that at the thirty-seventh session of COPUOS (June 6-16, 1994) this Moon Agreement revision was considered and it was recommended that no further action be taken, which the 49th General Assembly of the United Nations endorsed. While he says no new developments are expected on the issue in the near future, Hohenfellner did find interesting material on the subject which United Societies in Space, Inc. (USIS) submitted, commending their proposal for a Lunar Economic Development Authority. Unfortunately, this Committee failed to sufficiently review the position of critics of this unpopular lunar document, such as the opposition from the

National Space Society. The latter's position was that if lunar resource development were to be controlled by a monopolistic international organization, it would slow the process, discourage entrepreneurs, and possibly delay lunar settlement. This lobbying, especially over property rights, led to the U. S. Senate voting not to ratify the agreement.

Realistically, any international plans for lunar development will have to consider the implications of these two UN space agreements. Eilene Galloway, director of the Paris-based International Institute of Space Law, notes that while only nine nations originally approved this Agreement – its provisions are a problem for commercial entities and entrepreneurs wishing to exploit the Moon's natural resources. While the Outer Space Treaty accepted by the international community forbids national appropriation by means of sovereignty and is accepted in U. S. Constitutional Law, the claims of institutions and individuals on the Moon and its resources are still unclear. It would appear that exploiters or developers may remove such resources, but have no private property rights over them. Thus, S. Neil Hosenball, the U. S. representative to COPUOUS, made the case for the establishment of an "international regime" to deal with resources above or below the Moon. While the Outer Space Treaty makes the point that the Moon is the "province of all mankind," the Moon Treaty uses the terms "common heritage of mankind," requiring an international regime for the "equitable sharing" of lunar resources.¹¹

Since then a variety of nations have been undertaking a series of lunar missions. Several outcomes from annual international conferences point to a growing global consensus emerging on lunar development, particularly relative to exobiology on the Moon. Concurrently, energy scientists worldwide, including those within the Russian Academy of Science and Japan, are showing exceptional interest in lunar solar energy, whether beamed from the Moon or its orbiting satellites. Leadership is coming from a strategic and inter-national partnership being formed by proponents of wireless power transmission. Speaking at the International Astro-nautical Federation's 45th Congress, Dr David R. Criswell, co-inventor of the Lunar Solar Power System (see Appendix B), observed:¹²

By mid century 2050, lunar power industries can be sufficiently experienced and profitable to diversify into a wide range of other products and locations, other than solar power beaming. Specialized industries on asteroids and other moons will arise. Mankind can begin the transition to living independently off Earth. People can afford to move to space and return, allowing the womb of biosphere Earth to the evolution of other life.

1.2 Asian Lunar Initiatives

Japan has the oldest mission efforts toward the Moon in the region of Asia. Furthermore, Japan's Lunar and Planetary Society proposed to institute evolutionary lunar programs, involving orbiters and landers, roving robotics and telepresence, astronomical projects, habitat studies, and even tourism. As far back as 1994, Japanese business leaders and scientists urged that their government's Space Activities Commission invest in a 30-year, 3 trillion yen undertaking to build a Moon station by 2024, entirely constructed by robotics! Japan's Science and Technology Agency welcomed the proposal which included solar power generation. In July 1994, a

task force report of that Commission accepted those recommendations for Japan's space policy to include the building of a manned station and observatory on the Moon, preferably with its international spacefaring partners. In March 1996, Mitsubishi Corporation made a major investment in the ambitious plan of LunaCorp (Arlington, Virginia) to provide interactive robotic exploration of the Moon, as well as high-definition lunar video for space theme parks, television networks, and scientific research. In 1997, its space agency planned *Lunar A*, a lunar orbiter and penetrator probe. Exhibit 4 indicates the scope of imaginative Japanese macroplanning for the Moon.

>>>>.CONTINUED NEXT ISSUE, MMM #218

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"Mother Earth" & "Father Sky"

The Duality of the Human Environment

By Peter Kokh - kokhmmm@aol.com

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http://www.spacegeneration.org/newsletter/SGAC-Newsletter-Jul08_opt.pdf

The number of serious problems confronting the world at large today continues to grow, and become ever more difficult to manage with each passing day. The human race seems to be having a full-scale adolescent style crisis. If we do not soon emerge in fair shape, we may face something much worse than a worldwide depression -- a new Dark Ages. How long that would last and to what depths we might sink, dragging our host biosphere with us, cannot be known.

Population growth is outstripping our ability to access available resources at the standard of living levels with which we in the Developed World have become all too comfortable. Maintaining energy use at customary levels and maintaining the present state of "health" of the environment are beginning to look like either-or choices.

Poverty is on the rise in many areas, even in First World Nations. There is no end to a list of pressing top level concerns. Solutions requiring investment in one area, make investment in other areas harder to support. Are we caught in an "end of times" downward spiral? I think we need to take a look at just who we are, just where we came from, how we fit into the scheme of things as a people. If we can get a better insight into these things, we will have made a big step in putting the problems in the right context to begin to see solutions.

Most people consider our planet to be the only context in which we can understand our origins, our present history, and our future. One hears remarks such as "we need to find solutions to terrestrial problems right here on our home world, not out there somewhere." Well, quite frankly, it's too late for that. Our "home world" was Africa, and modern man has been on the move to wherever our developing technology would take us for at least 80,000 years. Our world used to be flat, but now we all consider it global. While few realize it, when man first set footsteps on another world, the "world" as a continuum of human horizons shattered that global limit forever; with that first step we became children of the Sun.

On every new frontier, we faced a new set of resources, of food sources, of climate conditions, of life-threatening dangers. Each time our great resourcefulness earned us the comfort of becoming "at home" in previously unforgiving, danger-fraught alien territory.

Backup a few steps to the real "Genesis." Of all the various elements of which our bodies are composed, only hydrogen is primeval. [Primeval helium is not found in living tissues, biochemical molecules, and substances.] All the higher elements have been forged in the interiors of stars which, at the end of their lifetimes, have exploded as "novas" scattering their enriched debris throughout the universe. It is from such "salted" gas and dust clouds that new stars began to form with attendant rocky worlds.

Genesis has it only half right. It should read,

*"Of stardust thou art,
And to the stars thou shalt return."*

Too many people think of Mother Earth alone. But where would we be without the Sun's light and warmth! Where would the Sun be without the countless older larger stars that ended their lives in a life-giving explosion? The Sun is but the most locally prominent part of Father Sky. Mother Earth and Father Sky are an inseparable pair. Together they constitute the holistic human environment. Without both, our existence and subsistence would be unthinkable. Nor can it be understood, preserved, enhanced, have a trans-adolescent future. We are children not just of Earth, not just of the Solar System, but of the Universe. "Mother Nature" is more comprehensive than "Mother Earth."

In that context, the suggestion that all solutions to our problems must be found here on Earth is not only wrong, but ignorant, stupid, self-defeating. Frankly, it is doctrinaire smelling of "orthodoxy."

Looking outward, the Moon *shares Earth's orbit* about the Sun. It is ours, a hinterland continent with resources for us to access and use. It is Earth's "pantry".

Yes, we have major energy, environmental, and social problems, all complexly interlinked. If accessing resources from space can help in any useful way in dealing with these crises, then assertions that we should look beneath our feet for all solutions becomes a cult of ignorance. And beyond the Moon are other resource-rich bodies, the asteroids, comets, and everything else in our Sun's considerable family.

Now the Environment seen as Earth alone, is clearly susceptible to the exponentially increasing effects of inhabitation by an excreting technological species. But what about the Environment seen as including "Father Sky?" The Solar System is, by terrestrial standards, very vast. Is it possible that we could in any sense pollute that larger ecosphere? Perhaps. Extensive use of mass drivers used to move small bodies such as asteroids, if the exit velocity were to be within a certain velocity range, could create small, limited but dangerous streams of pressure vessel-rupturing shot. Our possible negative effects on the solar environment are, however, hard to assess at this time. Let us hope our successors will be on alert.

On the positive side, Earth Life will accompany us as we spread the continuum of our presence beyond Earth's atmosphere. Sure, we could process some sort of Solyent Green nutrient to make it unnecessary to bring with us sustaining plant life. I will be most happy to have lived out my life in this "more primitive" age in such a case. The oasis of life that sustains us, is, in our opinion, not something to be outgrown.

Do we share the Universe

Looking out further, while the Moon seems to be barren, sterile, Mars may or may not be. But at best, any Martian life is stunted at a very low rung up the ladder of life. Around Jupiter, Europa's extensive ice covered global ocean hides mysteries about which we can as yet only wonder. The same may be so for other ice-covered moons of Jupiter and Saturn.

We know of advanced multicellular structured life forms only here on Earth. Are we alone? As mammals? as intelligent environment-modifying creatures? Many easy, flippant answers display an incredible ignorance of how very vast the universe is, not only in space, but also in time. No matter how rare "other" fertile "earths" may be percentage wise -- e.g. "one in a billion" -- the universe is so vast that there must be hundreds, even thousands of *billions* of other civilizations throughout quadrillions

of cubic light years and through the most recent two thirds of the time since our universe seems to have come of age. That said, our nearest "contemporary" neighbor might lie beyond the distance in both space and time within which there could be any meaningful interaction or exchange.

At any rate, it is most likely that the Universe is multiply fertile on a grand scale.

Humans and the Universe?

"Go and fill the world" in this expanded sense, begins to take on an interstellar connotation. Technology may limit us to much less than that. Some worlds will be able to support native born flowerings of life such as has Earth. Others may be able to support the beginnings of life, but not allow it to get much further. Others still may have all the needed resources but not the environmental conditions. Some grand beginnings will occur on planets whose suns are too short-lived to allow the full flowering such as that has happened here on Earth.

And there perhaps is our ultimate Genesis mission: to sow life where it could not have arisen on its own; to advance life where local conditions have held its evolution in check; to speed up evolution where the local Sun may be too short-lived. See "Welcome-Mat Worlds", MMM #45, May 1991, reprinted in MMM Classic #5, pp. 25-28 - at www.lunar-reclamation.org/mmm_classics/

It is not mankind that is called to return home to the stars, but Earthlife, Gaia herself. Earth-life cannot reproduce itself elsewhere on its own. Thus, with no apology to those whom the following makes them squeamish, an intelligent dominant species can be seen as the reproductive organ of its planetary Biosphere. Through us alone, can Earth-life, Gaia, Mother Earth spread beyond its current limits. Father Sky calls us to this pilgrimage home. It calls us to fulfill the destiny of Mother Earth, and in the process tap full endowments of the Mother Earth - Father Sky union, to save Mother Earth from the ill effects of our technological adolescence. Someday, when our civilization has become more adult, we will be Solarians, children of the Solar System.

As noted, our species is not originally "Terran" but African. We have been on an epic journey of expansion to one frontier after another. To stop now, in the belief that the world cannot be more than round, a belief as mistaken as the one that held the world to be flat, would be to turn our backs on ourselves, on our origins, on our destiny. We must not hide our light under the basket of Earth's defining atmosphere. We must continue to develop the depths of our given talents. We can only do that by accepting the challenge to keep pioneering new frontiers. What other way to continue to give praise and glory to the creative forces which have forged us?

Those of us who want to look outwards for help with Earth's intractable problems, are environmentalists too. But we see "environment" as a much larger bi-parental context. Our origin is on flat plains of Africa. Our destination is wherever our pilgrimage to keep on exploring our hidden given potential will take us. "Of Stardust thou art, to the Stars you shalt return."

Mother Earth is not a spinster but wed to Father Sky. Her terrestrial brood is but the first. We must reject the demands for terrestrial solutions to terrestrial problems. We must educate others to the much vaster space-time context in which we have come into being, and within which our future lies. ***Our Environmentalism must be holistic to be effective*** <MMM>

LUNAR ENTERPRISES AND DEVELOPMENT

Especially prepared for *Moon Miners Manifesto*.
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Installment 2

EXHIBIT 4 – Japanese Lunar Macroplanning



For over fifteen years, Japan has been calling for an international lunar initiative to include projects such as pictured here related to astronomy, habitat studies, and solar power. * *Source*: Boeing Corporation's artistic rendering by Jack Olsen.

But the Japanese found that there was a big gap between their ambitions and planning, as against actually doing and performing in outer space. The Japanese Aerospace Exploration Agency (JAXA) has had a series of launch postponements for two lunar missions, *Lunar-A* and *Selene*, costing some \$400 million. The former is designed to hurl missile-like impactors on the Moon's near its far side, so as to study the Moon's inner make-up. The later mission is designed to gather more scientific data on the Moon's origin and make-up - it consists of a main orbiting satellite and two smaller ones. *Selene* was launched from its Tanagashima spaceport, to provide serious remote sensing data. The largest lunar mission since *Apollo*, the Project Scientist Hitoshi Mizuani told *Space News* 7/20/04) that lunar exploration goes beyond its scientific value: *it provides inspiration, human extension to other worlds*.

Thus, Japan is actively seeking international partner beyond NASA and including cross-Pacific ties, so as to carry out its aspirations for the high frontier. Even its activities with the annual Japan-United States Science, Technology, and Applications Programs involve the private sector in North America. JAXA's focus now seems to be upon perfecting lunar instrumentation., so *Selene* will make use of 14 such science instruments. Whether there will be a "space race" between Japan, China or India, their engagement in lunar enterprise should also include alliances among progressive Asian nations within that region, such as Indonesia, South Korea, Thailand and even Vietnam.

China has a three-phase plan underway through its China Lunar Exploration Program (CLEP). Their China

National Space Administration initiated the first step in a one year Moon probe in 2008 using their *Chang'e 1* orbiter. This mission, named after a Chinese goddess who lives on the Moon, originated from the Xichang Satellite Launch Center in the southwestern province of Sichuan. Laun Enjie, chief commander of CLEP, reported that *Chang'e 1* carries eight primary instruments to photograph and map the lunar surface, probe its depth, study regolith chemical composition, and analyse the environment around the Moon. A payload data management system even includes 30 songs popular in the country, while the whole mission is estimated to cost about \$180 million. That is a serious investment in lunar exploration, so Laun stated that if the first mission, is successful, the Chinese hope by 2012 to land a lunar rover, and by 2017 return a lunar sample. Ouyang Ziyuan, a leading lunar scientist, elaborated that their automated lander would land on the Moon, so robots could snag and return soil samples.... For manned missions to the Moon, the Chinese are depending upon improvements in its heavy-lift *Long March 3-A* rocket which was used in this mission. They are planning to build such a spacecraft with 3-4,000 tons of thrust at a new launch site on Hainan Island in the China Sea. The new booster may be ready in eight years, and be able to lift up to 26 tons into orbit. Meanwhile, CSNA's third manned spaceflight, *Shenzhou 7* is scheduled for 2008.

India is an active player in the multi-nation move-ment toward lunar missions. By 2008, its Satish Dhawan Space Center expects to launch *Chandrayaan-1* atop their *Polar Satellite Launch Vehicle - XL*. The satellite will be placed in orbit around the Moon for possibly up to two years, and contain a deep space antenna system. Its devoted to high-resolution remote sensing of the lunar surface, including gathering infrared, X-ray and low energy gamma ray imagery of the Moon. Its payloads are coming from Indian experi-mentors, as well as from ESA, Bulgaria, and the U.S.A. Also incorporated is a Moon impact probe to test a future lunar landing; the device is designed to hit a predetermined location on the lunar surface. This will be a technology demonstration of a highly sensitive mass spectrometer, a video camera, and a radar altimeter.

Together these instruments hopefully will detect possible gases in the exosphere and provide video images of a prospective landing site. This unmanned Indian mission will carry two NASA scientific devices to find minerals and ice on the Moon. The Indian Space Research Organization has an agreement with the Agency to carry this payload on its 1,160-pound spacecraft, along with three instruments from European research centers. The international partnerships evident in this mission likely will lead to more scientifically and technically challenging cooperation on future lunar undertakings! At least that is the aim of ISRO chairman, K. Kasturirangan, after *Chandrayaan-1* ends its two-year mission.

All of the above Asian lunar missions are unique, and while there is some overlaps in coverage, they all advance lunar science and exploration. Combined data obtained and its analysis contribute to advancing human knowledge

1.3 European Lunar Initiatives

As previously discussed, European space organiza- tions have been pursuing lunar studies for

about 20 years, especially in conjunction with colleagues at international space conferences¹³. For example, the European Space Agency's International Lunar Workshop concluded on June 6, 1994 that both logic and timing make it apparent that the Moon is "a natural, long-term space station" and the "testbed for any plans of human expansion into the solar system," as long as such endeavors protect the lunar environment. Along with international delegates to those discussion in Switzerland, the consensus was that the world's space agencies must coordinate their lunar plans in a phased evolutionary approach. The ESA declaration that year observed optimistically that "current international space treaties provide a constructive legal regime within which to conduct scientific exploration and economic utilization of the Moon, including establishment of scientific bases and observations." The "Beatenberg Declaration" that emerged endorsed the four-phase lunar initiative, which we explained in the chapter on macrothinking. Exhibit 5 illustrates two such science prospects.

EXHIBIT 5 * - Lunar Science Opportunities



ESA studies identify specific astronomy/astrophysics prospects on the Moon's surface, such as illustrated above in the lunar telescope and below in the solar interferometer.



* Source: ESA reports, *Mission to the Moon* (SP-1150, 1992) and *International Lunar Workshop* (SP-1170, 1994). Also refer to N. A. Budden's *Tools of Tomorrow: Catalog of Lunar and Mars Science Payloads* (RP-1345) available from NASA/JSC (Mail Code SN2, Houston, TX 77058, U.S.A.)

The Europeans announced that their approach to the Moon is (ESA BR-101):

- founded on long-term objectives and a phased approach;
- would substantially increase scientific knowledge and exploit advanced technologies;
- afford wide public participation through advanced communications;
- would preserve the lunar environment.

Their 4-staged program includes (1) lunar explorers; (2) permanent robotic presence; (3) use of lunar resources; (4) lunar human outpost. ESA expects to use its upgraded *Ariane-5* transport system to deliver both lunar orbiters and landers, as well as to support possible geostationary transfer orbit.

The most recent ESA lunar accomplishment was *SMART-1*, a spacecraft that punched into the Moon's barren soil in September 2006. On a volcanic plain near the Lake of Excellence, thus ended a three-year mission of testing space technology while examining our celestial neighbor. At CFHT atop Mount Mauna Kea, Hawaii, their brand new WIRCAM recorded the impact site with its infrared mosaic. ESA coordinator on this Small Mission for Advanced Research Technology (SMART), Detlef Kochhny, operated from the project's ESOC in Darmstadt, Germany.

The purpose of the mission was to take a close look into the permanently shadowed lunar craters of the Moon's south pole, scanning it for possible ice. That resource would be needed not only for lunar dwellers, but when broken into hydrogen and oxygen, it provides breathable air and drinkable water, as well as being useful for making rocket fuel. Its launching on an *Ariane 5* rocket in September 2003, used ion propulsion for this ESA lunar probe.

Project scientist Bernard Foing emphasized the *SMART-1* data was being shared with other countries as a first step in collaboration for future missions to the Moon. The information gained includes surveys of lunar resources, polar illumination data, and characterizations of future landing sites. One aim is to develop common technical standards for future landers and orbiters. The next ESA reconnaissance missions are the *Mars Sample Return* in 2011, and the *ExoMars* in 2013, which would involve rover exploration. Are such missions simply replica-tions of what other space agencies have underway, and should limited resources be combined and concentrated initially on lunar development?

For more ESA information contact Bernard.Foing@esa.int.

Russia has been engaged in lunar research some fifty years. [14] After Soviet scientists shocked the world in 1957 with their first orbiting satellite, *Sputnik*, they began to devise plans the very next year for sending a small spacecraft to the Moon. Under the leadership of their great rocketman, Sergei Korolev, plans were even drawn up to fly to Mars and Venus! When their first moonshot missed in 1959, they followed up with the unmanned *Luna 2* which hit the middle of the lunar surface. A decade ahead of the Americans, this research lead to a soft-landing on the Moon of *Luna 9* in the Ocean of Storms I, January 1966. For four days that spacecraft sent back pictures of the rocky and cratered lunar surface!. That same year, *Venera 3* hit the planet Venus, while *Luna 10* continued the automated survey of the Moon. With the death of the "great designer," Korlov,

the driving force went out of this stunning venture into outer space.

For Russia, the Moon race had 2 sequels, according to author, Brian Harvey – the unmanned program which concluded in 1976, was a great success! In 1970, a year after *Apollo* landed the first men on the Moon, the Russians soft landed *Luna 16* in the Sea of Fertility, extending a robotic arm that drilled into the lunar surface and scooped up rock, and three days later returned it to the “motherland.” In 1972, *Luna 20* brought back more samples from the crater Apollonius, and later *Lunar 24* brought back a core rock sample 170.1 grams from the Sea of Crisis. But the robotic missions that were the most impressive were *Luna 17* and *21* – their 760 kg. rs *Lunokhods* rovers were solar powered with cameras, lasers, and other special equipment. These crafts were steered a ground crew back in Moscow’s mission control!

They accepted commands to drive, swivel, cross craters, and explore the terrain. *Lunokod 2* spent five months roving some 37km miles before using up its power... Unfortunately, the Russians manned lunar endeavors did not land cosmonauts on the Moon. Since 1964, their government set a goal of putting one of their citizens on the lunar surface. A giant Moon rocket was built, the *N-I*, which had 30 engines to fire the immense rocket. A second powerful rocket, *Proton*, was also built to send Russians to the Moon. The preliminary flights were beaten when the Americans *Apollo* program put two of their astronauts on the lunar surface in 1969. Russia never again gained the lead in the space race between the two superpowers, and so turned their attention away from the Moon to Mars missions. With the collapse of the Soviet Union in 1991, their space scientists shifted from research on space mirrors, to the big *Energiya* rocket, and the *Mir* space station.

In the 21st century, Russian space scientists are again turning their efforts back toward the Moon, especially in terms of international partnerships for lunar development. The Russian space agency’s budget has gradually increased, along with consultation with China and India on their lunar exploration plans. Both the head of Roscosmos, Anatoly Perminov, and chief of RSC Energiya, Nikolai Sevastianov, have made bold lunar statements in 2005, especially about putting humans back on the Moon. For instance in 2006, the latter talked about a Russian lunar base intended to mine helium-3 on the Moon as a rich source of energy. Energiya’s director spoke of a new spacecraft design, *Klipper* in partnership with ESA, which could possibly serve to transport helium, also proposed building a space ferry, *Parom*, that could be useful in assembling elements of a Moon mission.

But the Russian government has yet to fund their plans for further lunar exploration, nor has any other foreign government expressed interest in financing such ventures. Thus, the focus of Russian space missions is presently on cooperation in *International Space Station* missions which produce income via NASA contracts (\$1 billion annually).

One Agency project scheduled for 2008 is the Robotic Lunar Exploration Program (RLEP) Then Russians to launch a *Lunar Crater Observation* instrument – LRO will have aboard its spacecraft, a U. S. observation and sensing satellite. It remains to be seen how much of the \$104 billion that NASA plans to spend for a permanent

return of humans to the Moon by 2020 will be shared with Russian space scientists and engineers, or how much the Russian Federation would be willing to invest in a world lunar enterprise. But whatever the global space community agrees to do together on the Moon, there is much to learn from Russian space and lunar technologies. .

In an essay on “Space Travel – Sealing Wax and String,” *The Economist* (January 13th, 2007, pp. 71–2) refers to the “junior partners” in achieving American space goals. Lead by the European Space Agency, these include Australia, Britain, Canada, China, France, Germany, Italy, India, Japan, Russia, South Korea and Ukraine. The ESA strategy is to launch more robotic and science missions to the Moon and Mars. This London-based magazine favors the construction of and array of astronomical telescopes on the Moon, plus support for United Kingdom’s small satellites and miniaturized space instruments. The latter capability might then be used to build and launch *MoonRaker*, a lander intended for the lunar surface to date geological samples found there, as well as *MoonLite* to listen to noise of missiles fired into the Moon!

1. United States Lunar Initiatives

The United States of America has had two great lunar initiatives. The first was the seventeen *Apollo* missions to the Moon, begun in 1961 when President John Kennedy committed the country to lunar conquest within a decade, and prematurely terminated by President Richard Nixon in 1972. (Refer back to chapter 8.2). 15

Unfortunately, there was no follow-up on this magnificent milestone in human accomplishment, in terms of lunar industrialization and settlement. Many, like your author, argued that the American taxpayer deserved a return on their enormous *Apollo* investment – nearly \$20 billion! One columnist, Charles Krauthammer, lamented:

“Ours was the generation that first escaped gravity, walked on the Moon, visited Saturn—and then, overtaken by an inexplicable lassitude and narrowness of vision, turned cathedrals of flight into wind tunnels.”

Apart from media feats like Tom Hanks’ *Apollo 11* and his IMAX film, *Magnificent Desolation*, there were some hopeful signs during the past 36 years of lunar hiatus that the U.S. government would seek ways to provide a return on the public sector’s original expenditures for the *Apollo* missions to the Moon. These positive actions toward ROI were:

- (a) Since going back to the Moon permanently requires a robust, less expensive *space transportation system* with capability in both LEO and GEO, R&D funding was spent on new rocket technology which utilizes composite materials that will lower the cost to orbital access.
- (b) Further, the low cost *Clementine 1* mission sponsored by the U.S. Department of Defense’s Ballistic Missile Agency, in conjunction with the Navy and NASA, took 1500 pictures in February/March 1994. This produced the first global digital map of the Moon—multispectral imaging data of 34 million square kilometres. This automated exploration also found a mountain top that might sometime be valuable for the first human settlement aloft—in this

plateau the Sun never sets and a future colony would have full-time solar power by building a high collecting tower there¹⁶

After more than 25 years from the *Apollo* missions, NASA launched *Lunar Prospector* into polar lunar orbit in June 1997 where it crashed landed on the Moon's southern region in September 1999 (refer to Exhibit 130). It is part of the Discovery Program, a new way to do smaller, faster, cheaper innovative missions via competition among private contractors—in this case the award went to Lockheed Corporation, whose Dr Alan Binder conceived, designed, and developed the proposal for using a new LLV2 spacecraft. Supplementing previous automated lunar data collection missions, this one provided a global, low-altitude mapping of the lunar surface composition, gravity fields, and gas release events. The *Prospector* payload collected information that significantly improved our understanding of the evolution of the lunar highland crust, basaltic volcanism there, and lunar resource mapping. Mission adviser Dr. James Arnold, University of California—San Diego, noted that the new, simpler approach contrasts with previous NASA solar system exploratory missions, which often took too long and were too costly¹⁷

<MMM>

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To build a bridge one must have knowledge,
To know where to build it one must have wisdom.
Charles V. De Vet

Always listen to experts.

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

Extra-Terrestrial Engineering

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April 17, 2008 - Abstract

1 Introduction

Whether you look in Moon Miners' Manifesto, or other places, for ideas and inspiration about exploring, living or working off of Earth, the same kinds of problems come up. I suppose most people would claim that what is required is to think out of the box.

The problem is that our feet are anchored in the wrong box, not which box our head is in. For most of mankind's existence, what has defined us? Whether it is the Stone Age, the Bronze Age or the Iron Age, we have mostly been defined by the materials we use. Even advances in computers have been driven by our ability to understand and use materials.

2 The Moon

The Challenges of Using On Site Resources

If we are going to explore the Moon, live on the Moon, or work from the Moon; we need to work with the materials we have there. And almost every article one sees assumes at least some of what we are using to do this, is dug out of the Earth's gravity well.

If you are a mechanical engineer on the Moon, you have no iron or steel. If you are a civil engineer on the Moon, you not only have no iron or steel, you have no water and you have no bitumin. If you are an electrical engineer on the Moon, you have no copper.

But what about how easy it is to recover iron from regolith? Surely we will have iron? The iron of lunar night is not the iron we know on Earth. It may be easy to recover iron from regolith, lunar night is cold enough that iron is more or less a ceramic. The easy way to get usable iron and steel at those temperatures is to alloy with significant amounts of nickel. About the only easy use we will have for lunar iron is as a conductor in place of copper.

It should be possible with some effort to produce aluminum and titanium. We can probably cast aluminum into molds of wrought aluminum. No rolled aluminum, no extruded aluminum, no forged aluminum. Why? No iron or steel. Maybe we build a rolling mill out of our fragile iron, and only use it during the lunar afternoon, when things are warm enough for the iron to not be too brittle. How often are we going to show up at the mill to find that our iron parts broke during the night?

What about titanium? Molten titanium, "the universal solvent." Common around molten titanium on Earth is copper, something heat can be removed from fast enough so that a skin of solidified titanium protects the copper from the molten titanium. No copper.

Powder metallurgy is likely to be important for both of those metals on the moon. Has anyone ever built CIP, HIP, or other kind of metal powder equipment out of aluminum or titanium? We typically build all that stuff out of iron and steel.

The mechanical engineer will have it bad with no iron or steel, and no wrought products. Or, should lunar afternoon metalworking become available, the price for wrought products will be considerably higher, since the amount of time the plant can be open is so small com-

pared to the casting and powder metallurgy operations.

What about the civil engineer? While not everything they do revolves around iron and steel, we have no water to make concrete and we have no bitumin to make asphalt. They too will be working with materials they have not worked with before.

The electrical engineer will have a conductive metal to work with in iron. Brittle when cold, but the cross section might be small enough that elastic buckling will occur in preference to brittle failure. Small enough that thermal insulation might help to keep it warm, especially if it has current flowing in it and has internal heat generation. Again, it is a different material than they are used to using.

Above I have pointed out that those that design "things", will have to work with different materials, the effects are not limited to design. All of the trades are used to working with iron and steel (concrete, asphalt, copper wire, ...). Perhaps the largest effects will be the tools that people will be using. A stone hammer is going to work differently than a steel hammer.

The designers typically operate in an environment where learning is expected. They will have an easier time of adapting than others who are not expected to be learning on a constant basis.

One source of difficulty for all people, is that this very common material of today on Earth is anomalous. The effects of ferromagnetism on the properties of iron and steel are extensive. The replacement materials will tend to behave differently in many ways, some small and some large. For most people, "moving" to some environment off of Earth is very much like taking people and moving them back into the Bronze Age or the Stone Age. Many assumptions about how to do this, what to do things with, what tools to use, etc. will need to change.

3 Railroads



MMM #213 had articles about railroads. Materials assumptions abound. Nothing I don't think that can't be allowed for. Railroads are possible. I suspect that their similarity to those on Earth will be limited to 2 "rails" separated by some distance. With gravity being about 1/6th of Earth, downward forces will be much lower. Forces on cornering will be the same as Earth, as they are dependent on momentum, not gravity.

In the near term, we are not going to have wrought rails. Powder metallurgy seems like a reasonable way to produce rails, for reasons I'll get into. The thermal expansion problem mentioned in MMM #213 exists (on Earth) for two reasons: thermal expansion does happen, and the metal is highly incompressible.

On the Moon, we probably can get away from the

incompressibility part of the problem. If we are making rails via powder metallurgy, our final product is a mix of whatever metals we are working with (which is quite incompressible) and void (which is very compressible).

If we build the rails by drawing them out of a forming press/oven, we can produce rails much longer than the press/oven. Which is similar to what we have now, long rails. Via powder metallurgy, we should be able to arrange that the green density (and the finished density) along the rail's length is actually modulated, alternating regions of high theoretical density and lower theoretical density. Ideally we design this modulation to take up all the thermal expansion stress. We do want the distance between higher theoretical density peaks to be small enough, that ride characteristics do not see the modulation. With such a rail, it is likely that we want to install rails when they are coldest (and hence shortest). If a rail fails, we need to wait until some time between midnight and morning to replace them.

It is possible that we may need to run fiber reinforcement along the sides of the rail, or incorporate extra traction in fastening the rails to the "ties" to provide stability with our less than theoretical density rail solution to thermal expansion. One idea for producing solar cells on the Moon's surface, had a robot build the solar cells from native material as it traversed the surface. Such an idea might work for railroad ties.

I would expect that the properties of regolith at any given point are not ideal for making ties. What would be nice is if we can augment the local regolith properties with lunar derived materials, and then sinter "in place" a railroad tie. Depending on the sintering conditions, we may be able to incorporate fiber or bar reinforcements along the length of the tie (perpendicular to the rail direction). It may be that our railroad ties end up being ceramic reinforced (residual regolith) sintered aluminum with titanium "rebar" sintered into the tie. Aluminum certainly has properties which compare with wood (a common railroad tie material), and should sinter at temperatures which will not compromise any "titanium" fibers or rebar which is present.

On Earth, oxygen is pretty much everywhere. Our railways are steel wheels (with an oxide surface) rolling on steel rails (with an oxide surface). It is an oxide rolling on an oxide. If the wheels are locked up in an effort to stop the train, there is still enough oxygen around, to keep a metallurgical bond from forming between rail and wheel (once stopped).

This is not true on the moon. Our metal rails and metal wheels will likely have metallic, not oxide contact. Metallurgical bonding will be of concern at all times, not just emergency stops. As far as braking is concerned, we have 3 options on the Moon.

- We can incorporate magnetic braking, since our rails are likely to be something paramagnetic (like aluminum).
- We can incorporate linear generators into the track at locations where braking is known to be needed, and hence possibly recover braking energy by turning it into electricity.
- We can put retrorockets on trains. For planned braking, the second option is the best one. For unplanned stops, we will need the first option, and for safety we probably need to have the third one. The option not listed, is the normal one on Earth,

mechanical brakes acting on the wheels. We cannot afford to have the wheel “weld” itself to the rail just because the brakes were applied. Possibly this option is used at low speed, or with minimal force. As a general solution, I don’t believe it is viable.

4 Extra-Terrestrial Materials Science and Engineering

Engineering on Earth has been severely effected by its surroundings. Iron is abundant, and useful. We often do not think about what material to make anything out of, we just find what kind of iron based material we have available. Excessive use of iron coupled with economies of scale, has made iron and steel less expensive than it should be. Which makes it doubly difficult for any other material to be used for any given application.

With iron and steel used so much, there is a scarcity of people who have used anything other than iron and steel. To move into space, we need to become material neutral, and use the best material that is available. And best needs to move away from definitions based on up-front, installed cost. Life-cycle costs would be a reasonable thing to work with; there are others. GH

Gordon Wayne Haverland

Gordon is a founding member of The Moon Society (#794), having joined Artemis Society International in September 1999, ten months before the Moon Society Founding Convention.

Gordon currently lives in Grand Prairie, Alberta, Canada, about 260 road miles WNW of Edmonton, not quite the same distance NNW of Jasper, and almost 500 miles NW of Calgary, home of the *Calgary Space Workers* and *Calgary Space Society*.

His area of expertise is Materials Science, making him especially qualified to write about the topics covered in this article.

Website: <http://www.materialisations.com/>

Resources Relevant to next article

ET Debate 1994 – collected, edited and archived by Patrick Patriarca, included find all 4 sections of the External Tank debate which took place on the SPACE Conference on FIDONET in 1994.

<http://www.orbit6.com/et/ngfido94.htm>

Report on Space Shuttle External Tank Applications [Paperback]

[Alex Gimarc](http://www.amazon.com/Report-Space-Shuttle-External-Applications/dp/B002MB3HYQ/ref=sr_1_10?s=books&ie=UTF8&qid=1306089323&sr=1-10) (Author) available at Amazon.com \$24.95
http://www.amazon.com/Report-Space-Shuttle-External-Applications/dp/B002MB3HYQ/ref=sr_1_10?s=books&ie=UTF8&qid=1306089323&sr=1-10

Utilization of Space Resources in the Space Transportation System

<http://www.nss.org/settlement/nasa/spaceresvol2/utilization.html>



The External Tank = End of an Era? A Call to Action

From James W. Barnard <traildr@ecentral.com>
Denver Space Society, NSS



It has been reported in several places (Orlando Sentinel, Stephen Metschan’s article on The Space Review website, posts on Space.com, etc.) that NASA will begin dismantling/destruction of the tooling used to manufacture the 8.4m diameter Space Shuttle External Tank (ET) at Michoud, NEXT MONTH! The ostensible reason for beginning next month is to clear room for production equipment to build the 10m dia. tankage for the Ares V heavy-lift launch vehicle.

So, what’s the big deal? Don’t we want the big Ares V that will take us back to the Moon? The answer is, “Yes...but!” The facts are as follows:

The Space Shuttle system is due to be retired not later than September 2010 (possibly as early as May 2010, according to NASA).

The Orion/Ares I portion of the Constellation system is supposed, by Congressional edit, to fly the first manned mission no LATER than September 2015. NASA’s schedule was originally supposed to move that date in to September 2013. In the last week or so, that date has been moved back one whole year to 2014, due to budget shortfalls, and developmental issues! If that slips, it means that the United States will have NO launch capability to the International Space Station (ISS) of its own.

Originally, we were to depend on the Russians for Soyuz spacecraft and launch vehicles to provide the U.S. and other countries access to the ISS, until at least Ares I/Orion is available. Although the Russians have *not* given any indication that the current international situation will affect their willingness to provide such services, Congress must, in the next few months, approval an extension to the waiver of the ITARS ban on paying money to anyone doing business with Iran (which the Russians do). Although I can’t quote the source, it is reported that a senator or congressman has said that waiver will be “dead on arrival”!

There is a possibility that the Shuttle’s retirement date could be extended to cover the gap between it and

Initial Operational Capability (IOC) of the Constellation hardware. But there might not be enough external tanks available to fly the orbiters, once the current inventory of ET's are used up.

In addition, there could be considerable problems with the Ares V design. It has already grown from five (5) to six (6) engines on the first stage, necessitating rear-rangement of the engine positions to avoid exhaust impingement problems with each other, and the SRM's! And the Systems Requirements Review won't even be held for awhile, let alone a Preliminary Design Review (PDR).

If it should turn out that the Ares I/Ares V concept proves impracticable, it might be necessary to turn to other options that could utilize the 8.4m diameter tankage tooling at Michoud. But, if that option is force-closed by destruction of the tooling, we may be left with *no options at all!*

Please keep in mind that this situation will apply regardless of who wins the November Presidential election. If the tooling is destroyed in September, the next President will have NO options to utilize it, regardless of who is the winner of the election! Congress will not be in session before the destruction of the tooling begins, and probably wouldn't be able to come to any agreement on legislation to prevent the action! Note, that the tooling can always be dismantled at a later time if it becomes clear it is no longer needed.



It is imperative, therefore, that we, who believe in the advancement of space exploration by the United States of America, contact President Bush, requesting that he issue an Executive Order prohibiting dismantling/destruction of the ET tooling at Michoud, and also to stop continuation of other, similar activities that support continued Shuttle flights, if it is decided by the next Administration and Congress to do so.

How to do this: You may e-mail the President at the White House at comment@whitehouse.gov. You can also FAX the President at 1-202-456-2461 or phone 1-202-456-1111.

What to say: Above all be courteous! *Do not demand* anything! *Respectfully request!* Site the *facts*, as you know them. If you can uncover additional confirmation of the dismantling of the tooling, do so. Leave politics out of this! I am undecided if group signatures, such as identifying yourself as a member of the Moon Society, NSS, etc., will be helpful or not. If one has a technical background, you might want to identify your-

self as such. You will (and I have) probably need to identify yourself including name, address, phone, e-mail, etc.

If we can get this information out to a maximum number of people, we may get action by President Bush ... although there is no guarantee the word will even reach him through White House "filtering".

All we can do is try!

Ad Luna! Ad Ares! Ad Astra!

James W. Barnard

trailrdr@central.com

Denver Space Society, NSS

MMM #219 - OCT 2008

IN FOCUS Using the Green Movement to Advance Technologies Needed on the Lunar Frontier

In our article "Books on the Moon" pages 5-6 this issue, we write about Amazon.com's new electronic book reader, the Kindle, as a prototype for what we'll need to read books in a situation where paper will be as priceless as platinum. Amazon's Kindle will appeal to Green enthusiasts (we are one of them) but, of course, Amazon.com went forward with this project for profit motives. But that is immaterial. What counts is that Kindle will also appeal to those who would like to find ways to slow down deforestation. Forests help keep the atmospheric cycle healthy, serving as sinks for carbon dioxide. That is especially important as we continue to produce ever more CO2 as consumption of fossil fuels continues to increase as the "Third World" continues to accelerate its already rapid "catch-up" pace.

Inorganic Substitute for Wood Furniture

On the Moon, you can forget about wood "case goods," furniture industry jargon for wood furniture such as dressers, tables, etc., including bedroom sets, dining room sets, etc. So if we can leverage the Green Movement to slow deforestation by switching from wood case goods to a substitute (definitely not plastics derived from fossil fuels) that will not only help slow deforestation but will develop prototypes of something we will need a lot of on the Lunar Frontier. One possibility here is to predevelop glass-glass composites as a substitute furniture material. Just as there is plenty of sand and rock dust on Earth, we have an inexhaustible supply of rock powder and dust on the Moon - called "regolith" or more simply "Moondust."

We've been pushing this for twenty years, and now we have at last a strong incentive to predevelop this technology for making profits here on Earth, hitchhiking on the growing Green Movement. See: http://www.lunar-reclamation.org/papers/glass_composites_paper.htm

In our article in MMM#4 April 1987, "Paper Chase II" www.asi.org/adb/06/09/03/02/004/paperchase2.html we discuss possible substitutes for a variety of wood and paper uses: labels on cans and bottles, posters, letters and greeting cards, wrappings and packaging, and much more. For the Moon, the economic incentive is of "make or break" priority. While at the present, wood and paper substitutes are not always really cost competitive, the motivation of those seeking Green Solutions, especially solutions that slow deforestation, is strong enough to

provide a test market for new products that could serve as prototypes for wood, paper, and plastic substitutes we will absolutely need on the Lunar Frontier.

While we don't expect most environmentalists to care a bit about the needs of future lunar pioneers, those space space enthusiasts who do care, can now look for economic support from the Green Movement to help introduce such new products even at a some competitive disadvantage. In other words, the enterprising among us Lunnies ("Lunans") can attempt to predevelop such products in an atmosphere where cost-comparison is not a factor for a growing percentage of those willing to pay a bit more to reduce their "carbon footprint." Ordinarily, new products are at some cost-pressure disadvantage by having to amortize quickly the development costs involved in bringing them to market.

What we are saying, is that right now we have an increasingly more friendly environment in which to predevelop some of the many technologies that will be needed to make a Lunar Frontier work economically in a situation where wood-paper-plastics, ultra-cheap on Earth because of our enormous biosphere, will be ultra-expensive on the Moon where there is no existing biosphere to tap, and where the elements needed to develop a biosphere (hydrogen, carbon, nitrogen) are quite rare.

If you are a Moon guy, and an entrepreneur who wants to help, but needs to make money *now*, this is your big chance. Read the articles cited! <PK>

LUNAR ENTERPRISES AND DEVELOPMENT

Especially prepared for *Moon Miners Manifesto*.

© Philip R. Harris, 2009 - PhilHarris@aol.com

Installment 3

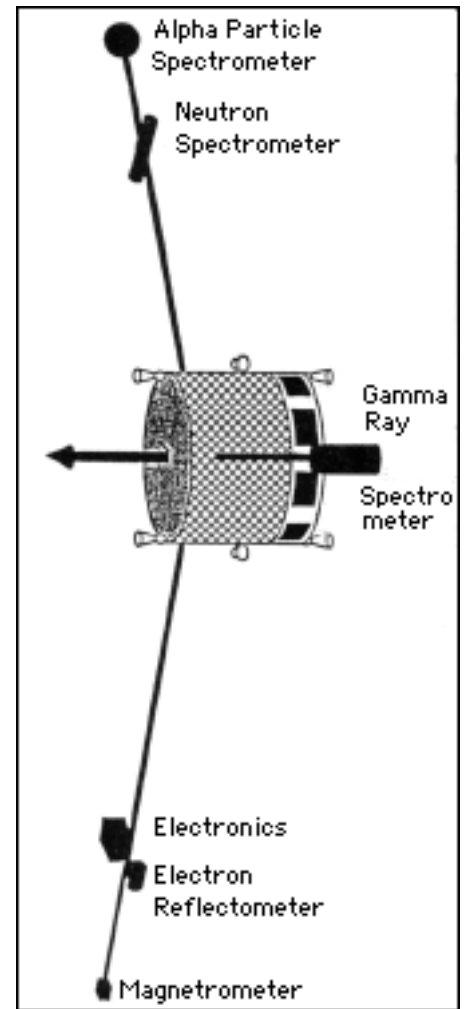
EXHIBIT 6 - Lunar Prospector Mission

Mission Objectives

Low altitude map-ping of surface composition, magnetic fields, gravity field and gas release events to improve our understanding of the origin, evolution, current state and resources of the Moon.

Mission Development Timeline

Authority to Proceed Feb '95
 Prelim. Design Review May '95
 Official Design Review Sept. '95
 Final Design Review April '96



Lunar Prospector - booms extended & instruments

Mission Profile

LLV2 Launch in June 1997 - Minimum Energy Trajectory
 2 Mid Course Maneuvers - 3 LDI Burns
 1 Year Nominal Polar Orbit Mapping Mission
 - 100 kilometer Altitude - 118 Minute Period
 - Orbit Maintenance Every 44 Days
 - Extended Mission?

Exhibit 6 —Lunar Prospector Mission Profile.

The last unmanned lunar mission of the century by NASA, summarized above, produced critical information on the lunar poles, such as detecting ice possibly stored there.¹⁷

17 * Source: P. Dasch, "Lunar Prospector," *Ad Astra*, May/June 1995, pp. 32/33; www.nss.org. For current information on lunar missions, consult, *The Space Report - The Guide to Global Space Activities* published by the Space Foundation (www.TheSpaceReport.org).

(d) *National space legislation*—in 1995, a "Back to the Moon Bill," part of an Omnibus Commercial Space Act, was introduced into the U.S. Congress—while limited in scope, it would create a legal regime for NASA to purchase lunar data from private enterprise, allowing commercial companies to conduct innovative lunar probes on their own designs. Sadly, it never became national legislation or policy.

The second great American lunar initiative incorporated into our way of life. VSE's goal is to extend ongoing, part of the national policy called the *Vision for Space Exploration*. Inaugurated by the second President by name of George W. Bush in 2006 and endorsed by an act of the U. S. Congress, this endeavour tasks NASA to move toward unmanned lunar probes by 2008, and manned missions by 2015, with a goal of returning permanently to the Moon by 2020. The plan is both incremental and cumulative to develop the necessary "Lunar Architecture," beginning by again scouting the Moon with automated lunar trailblazers until astronauts can begin to establish a lunar outpost.

The "Global Exploration Strategy" emerged in 2006 with the participation of 14 space agencies and assistance from over a 1,000 experts. This produced 200 objectives that might be pursued on the lunar surface. There was agreement that its principal objective is to create a sustainable human and robotic presence on the Moon that opens significant opportunities for science, research, and technological development. Both the VSE and GES makes it clear that other national partners in this lunar enterprise are welcome to share the risk, the costs, the glory, and the eventual benefits! With a \$16 billion budget until 2010, the Agency's Exploration Systems Mission Directorate, has been transforming "the vision" into a *bona fide* space program that includes signing contracts and building hardware. All this has to be done while NASA and its partners complete the *International Space Station*, retire the shuttle fleet, and replace it with *Ares* and *Orion* spacecrafts, now in the testing and building stage. A series of sorties to the Moon's poles and equator, reaching lunar sites that were never visited by *Apollo* expeditions, are planned for both robotic and human missions in the next dozen years.

The outpost, which will be developed into a larger base, apparently is to be located at one of the lunar poles, probably in the south to start. The *Lunar Reconnaissance Orbiter* to be launched in 2008 will determine that exact site. The Lunar Architecture Team is working a series of expeditions that would culminate in spacefarers living on the Moon for up to six months. A lunar transportation system is being planned so that each lunar landing, unmanned or manned, will include critical pieces of the new lunar infrastructure. By the end of the next decade, the second group of moonwalkers are expected to include 7 astronauts who bring their own habitats and will likely stay at the start for at least a week. A second-year mission would deliver power generation equipment, unpressurized rover, and other infrastructure. The gradual-build up on the Moon will include extending human stays for 14-days, then 30-days and so forth as each year the mission duration is extended up to possibly six months or more.

Initially, the emphasis will be upon lunar resource utilization or ISRU aimed at self-sustaining operations. Much will depend on available U. S. funding, and agreements at to the contributions of other national space agencies to this macroproject.

The imaginative *Vision for Space Exploration* is about more than merely returning to the Moon for the benefit of earthkind. 18 As Dr. Paul Spudis of Applied Physics Laboratory reminds us, it is to increase human knowledge about the objects trapped in gravity by our star, the Sun, and everything else. In the future, the material trapped in the Sun's vicinity could be

extended into our way of life. VSE's goal is to extend humanity's reach beyond low Earth orbit and destinations within cislunar space, and then further out into our Solar System. In the process, we will learn new skills and technologies that will eventually be commercialized. It could occupy human ingenuity throughout the 21st century!

Meanwhile, the Mars advocates are encouraged because VSE implies that the Red Planet is the next logical target for manned missions beyond the Moon. While continuing to Mars will be most dangerous and costly, the learnings from establishing a lunar base should facilitate that process, especially in terms of a launch pad. Members of the Mars Society estimate that a Mars' manned mission would be possible for an investment of \$100 billion, and that one third of the NASA budget now should be devoted to that objective. The search for microbial life there is seemingly worth the effort. In the meantime, robotic exploration of Mars proceeds - in August 2007, a *Delta II* rocket launched a lander *Phoenix* on a nine months journey to study its icy soil. If all goes well with the spacecraft parachuting on the frosty Martian plain, it will be NASA's most northern landing there, a first possibly in capturing and analysing any water that is found. The \$420 million mission will be worth it, if liquid water is obtained a little south of Mars' north pole! Such efforts confirm that that the purpose of VSE is more than establishing a human presence on the Moon, but to use what we learn there to go beyond, starting with Mars. 19

At NASA's JPL, Dr. Martin Lo designed the flight path for the *Genesis* mission in 2002 to collect solar wind particles. Then he recommended formulation of an **interplanetary superhighway** to make space travel easier. Lo envisions a place to construct and service science platforms around one of the Moon's LaGrange points. The latter are landmarks of this interplanetary superhighway to planets, asteroids, and comets. Dr. Lo thinks spacecraft could easily be shunted to and from these lunar stations for maintenance and repairs. By using this "freeway" through the solar system, the amount of fuel needed for future space mission could be slashed (www.genesismission.org).

1. **Private Lunar Initiatives**

Farsighted business leaders and entrepreneurs recognize that we are in the process of creating a twin-planet economy, and new wealth can be gained on the Moon that will eventually contribute to a thriving and prosperous society on both planets. But to take advantage of lunar opportunity is a very costly and risky investment. Without the aid of the public sector, private lunar enterprise, in the beginning, will rely on government contracts, grants, tax incentives, and other forms of subsidy.

In 2004, the Presidential Commission on *Vision for Space Exploration* issued a report highlighting the importance of private enterprise in this national endeavour. But will the U. S. Congress and Administration provide any incentives for that participation? Dr. Wendell Mendell, Lunar & Planetary Exploration chief for NASA, made it clear in an e-mail to the author (12/12/06) that the Agency does not believe that it should be or can be in charge of settling the Moon. Obviously, this will be the business of private enterprise, starting first with lunar contractors, tourists, and then recruiting lunar dwellers.

Again, in the exploration of the New World in the 17th century, it was the trading companies who signed up, transported, and initially supported the colonists. The research of Jonathon Karpoff at the University of Washington confirms that historically in the exploration of previous frontiers, private expeditions were better organized, more adaptable, suffered fewer fatalities, and made the better use of the latest techno-logies! And so it is likely will be the case in the settlement of the Moon and Mars.

In the 21st century, there are currently few lunar entrepreneurs because of the enormous costs involved in financing a venture, and the inability of raising sufficient funds for lunar projects. It stopped a joint venture exploration mission by LunaCorp with Radio Shack from sending the *Superstar* telecommunications satellite to map the Moon.

That also was the experience of Dennis Laurie, CEO of TransOrbital, Inc. (www.transorbital.net). TO was the first commercial company to receive license approval from both the U. S. State Department and NOAA to launch a mission to the Moon, beyond geosynchronous orbit. The strategy was to send into orbit, and then land a private small spacecraft, *Trailblazer*, on the lunar surface. With photovoltaic cells on each side, power could be independent of orientation and polar orbit. The craft was reconfigurable in design, and capable of carrying a host of payloads. The primary purpose was high-definition lunar imaging of the Moon and nearby objects of interest that might prove of value in planning future lunar missions and landing. Apart from the income produced from the sale of its lunar images, TransOrbital's market was to be the selling of offworld advertising and public relations by Internet packages, television documentaries, brand naming rights, as well as transportation to the Moon of business cards, messages, and personal or commercial products, plus sale of post-launch extension products. In conjunction with International Space Company Kosmotras, TransOrbital managed in 2003 a successful test launch of its *Trailblazer* satellite from the Baikonur Cosmodrome in Kazakhstan on a *Dnepr LVSS-18* intercontinental ballistic missile.

Although TransOrbital had the support of both Space Age Publishing and Lunar Enterprise Corporation, it could never obtain sufficient sponsors or investors to make a final launch to the Moon, or achieve its \$150K a month projected income stream. TransOrbital was a magnificent commercial space effort ahead of its time and pocket book.

Entrepreneurs have proposed many business projects for the Moon, most of which are premature. For example, Dave Dietzler want to use the lunar surface for farming (EM: Dietz37@msn.com), while other want to dig down into that surface and build storage units for archives from Earth, as a protection to a catastrophe on the home planet. Another imaginative proposal comes from the Alliance to Rescue Civilization to develop a DNA repository for all life on Earth that is stored at a lunar base (www.arc-sapce.org/). ARC would also deposit below lunar regolith, a compendium of all human knowledge. Its founder, NYU professor Robert Shapiro argues that civilization must protect the things it values.²¹

More imminent is the Centennial Challenge Prize offered in 2006 by NASA and the X Prize Foundation for private sector innovators. Within context rules, the \$2.5m

Lunar Lander and Vertical awards go to the competitor providing the best rocket demonstration of a trip from lower Earth orbit to the Moon. The Agency hopes to contract with the winner/s, and intends to continue the program with other lunar challenges as a spur to space entrepreneurs.

Universities are examining prospects for their own lunar missions, seeking alumni support – for example, *Stanford on the Moon* and *Iowa on the Moon*. The former was started by alumnus Steve Durst, founder of Space Age Publishing, to initiate the university to lunar enterprise. The latter refers to Iowa State University whose alumnus, Dr. David Schruck, who has urged professors and students at his Alma Mater to consider research relative to in-situ resource utilization (ISRU), directed specifically toward a lander and robot in the equatorial region of the Moon. This aeronautical engineer/physician recommends that a consortium of universities might be formed to design experiments, including lunar manufacturing (EM: docscilaw@aol.com).

Non-profit organizations have also dabbled with projects for the Moon. The oldest venture, which coordinates efforts of some ten other groups is The Artemis Project (www.asi.org). This 1997 ambitious plan of Lunar Resources Company proposed a four-step mission: (1) crew assembles spacecraft at LEO space station, mating it with a Lunar Transfer and Descent Stack; (2) the Lunar Transfer vehicle then ferries the Descent Stack to the lunar orbit, and (3) the DS lands on the Moon, providing a habitat for spacefarers as the LTV remains in lunar orbit during the exploration period; (4) crew levels the stack as a solar power station and antenna, then spend ten days exploring before returning to Earth. It makes for a wonderful graphic, but sufficient funds were never raised for the venture, while VSE actually moves ahead with NASA's lunar return.

A more realistic plan was put forth in 2007 by Steve Durst on behalf of the International Lunar Observatory Association. ILOA is in the process of fundraising from sponsors, affiliates, and investors to erect a multi-functional lunar observatory at the Moon's south pole near "Malapert" Mountain, possibly before 2010.

SpaceDev Inc. has been contracted to develop a lunar lander demonstrator model. The ILO lunar commercial communications center will include a power station for transmission to Earth of real-time astrophysical data and videos

EXHIBIT 7 * Planned International Lunar Observatory

In 2005, a Lunar Commerce Roundtable was held to discuss prospects for business endeavors on the Moon (www.lunarcommerceroundtable.com/) The participants examined how such enterprises could contribute to the global economic growth foreseen in the *Vision for Space Exploration* (refer to chapter 1.2). A key conclusion was that publicly-funded exploration should facilitate an open approach to lunar development that provides flexibility for private and public sector stakeholders. In lunar entry and exit, these entities need to practice both collaboration and innovation in creating a commercial market on the Moon where government is only one of the many customers. This "eighth continent" is both accessible and offers commercial opportunities in energy, transportation, mining, construction, manufacturing,

entertainment, advertising, branding and sponsorship. With the assistance of robots, markets will emerge that are profitable and beneficial to human there and on the home planet!

But such cislunar undertakings are fraught with risk, both on the ground and aloft, requiring more user-friendly legal and regulatory practices, as well as helpful financial incentives and provisions if lunar partnerships are to flourish. To succeed in a bi-planetary economy, exhibit 8 predicts the activities that should be pursued. Each will require macro-thinking and micromanagement.



Planned International Lunar Observatory. Private enterprise is now fundraising for this non-governmental telescope on the Moon . *

Source: International Lunar Observatory Association (480 California Ave. # 203, Palo Alto, CA 94306, USA; www.iloa.org).

EXHIBIT 8 * – Lunar Enterprise Forecasts

If a lunar macro-project is undertaken by a global government consortium or trust, then provisions should allow for participation by private enterprise. On the other hand, some lunar commercial possibilities should be left entirely to the private sector to underwrite, manage, and develop. Non-profit organizations, such as universities, professional and scientific societies, humanitarian associations, should be encouraged to become lunar sponsors in their fields of expertise. To optimise a lunar economy for the benefit of humanity, here are some areas for R & D:

- Space transportation systems to and from the Moon, including spacecraft and fuel depots;
- Lunar transportation systems across the Moon's expanse and beyond, including lunar fuel production from oxygen;
- Lunar supply systems in terms of food, water, materials, inflatables, and equipment until such can be produced on the Moon itself;
- Lunar concrete, water, and in-situ resources that will contribute to the construction of infrastructure there;
- Lunar dweller systems – habitats, regenerative life support systems, radiation shielding, food management, waste management, health services, thermal controls, et al;
- Lunar science and engineering provisions to further research by scientists, astronomers, biologists,

geologists, resource mapping and analysis, behavioural science experimentation, etc.;

- Lunar communication systems for use on the Moon and with the home planet;
- Lunar energy production and distribution, especially scale-up a solar electric power system, and eventually a lunar solar power system to beam energy to Earth;
- Lunar construction systems utilizing bi-planet materials and technologies;
- Lunar mining and manufacturing systems, such as with regolith and Helium-3;
- Lunar governance and administration that encourages peaceful, commercial, and collaborative development of the Moon's resource;
- Lunar financial, real estate, insurance, liability, and legal services, etc.;
- Lunar educational and cultural systems for both *Selenians*, as well as programs to be transferred from the Moon to Earth, and vice versa;
- Lunar entertainment and performing/creative arts provisions for inhabitants and visitors;
- Lunar security and peacekeeper provisions, including conflict resolution and a justice system to deal with delinquent deviant and criminal behavior;
- Lunar tourism industry and provisions for visitors from Earth;
- Lunar design and manufacturing of spacecraft to go to Mars and the asteroids;
- Lunar manufacturing of telescopes, tools, and instruments made of Moon materials;
- Lunar resources, products, and services for the benefit of the Earth's inhabitants;
- Lunar production and deployment of free-floating structures and vehicles in outer space;
- Lunar enterprises to help create a spacefaring civilization that can be hardly imagined now, as human knowledge and potential expand offworld!

Exhibit 8 – Lunar Forecasts. Expert consensus on human development of the Moon in 21st Century. *

Source: Drs. Lawrence L. Kavanau, DOD deputy administrator who helped forge the vision and policy that led to the *Apollo* program that landed humans on the Moon (this aerospace engineer of rare business acumen died in 2005)....

David G. Schrunk, aerospace engineer and radiologist, senior author of two editions of *The Moon: Resources, Future Development and Settlement (2008)*, and founder of the Quality of Laws Institute...

Philip R. Harris, behavioural scientist and management/space psychologist, author of three editions of this book, *Space Enterprise: Living and Working Offworld (2008)* and the classic *Managing Cultural Differences (7th ed., 2007)*.

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The innovator has for enemies all those who have done well under the old conditions.

- condensed from Machiavelli

From now on, we live in a world where men have walked on the Moon. And it wasn't a miracle! We just decided we wanted to go.

- Jim Lovell, in "Apollo 13"

"One doesn't discover new lands without consenting to lose sight of the shore for a very long time."

- A. Gide



(not about the Moon)

by Peter Kokh

Back to the Future

In the early 1980s, when I decided to write a novel about where we could have been then, had we not retreated from the Moon in 1972 (on Mars, obviously!), this Mars enthusiast figured that since getting our feet wet on the Moon first would have been necessary to open a frontier on Mars, I would have to start the novel by sketching how we would do the Moon. Realizing that the Moon's deficiency in carbon and hydrogen and nitrogen would make many of the products we were used to using in our consumer economy prohibitively expensive, we started out trying to come up with ways we could substitute, or make do without, "wood, paper, plastics."

In MMM #4, April 1987, our article "Paper Chase II" attempted to tackle how we might substitute for, and do without paper, an enormous part of our everyday lives www.asi.org/adb/06/09/03/02/004/paperchase2.html This article has been reprinted in MMM Classics #1, p. 11, in PDF file format, as a free download from:

www.moonsociety.org/publications/mmm_classics/

In this article, we tried to find appropriate workable substitutes for most categories of paper use. What would future lunar pioneers do for books? Producing them from lunar materials would be exorbitantly expensive, and so would importing books made on Earth.

"Books, magazines, newspapers: electronics to the rescue, you say. Well *only if there are some quantum leap improvements over what is available today*. Cathode ray tube (CRT) eye strain is a common enough complaint to show that the final format of electronic reading media is not yet on the scene. The Lunar "EZ-Read" must not only be eye-friendly, it must be lightweight, even pocketable. Rainbow-color capacity should not be a luxury.

Electronic books, magazines, and newspapers, etc. to be inserted into the reader must be quite compact especially if hydrocarbon plastics are involved so that the weight ratio to paper replaced is as high as possible. All metal alloy and/or silicon would be the best."

Now, some 21 years later, it appears such a "reader" is available. Amazon.com, looking for a cheaper way to sell more books, has come up with such a device, the **Kindle**. You can now download whole books, newspapers, and magazines, for a fraction of the cost of a physical copy, even at Amazon.com's bargain prices.

About Kindle

There is probably little we can do to prevent this article being interpreted as a sales pitch to go out and by your own Kindle. But there is no other way to clarify the enormous possibilities. Keep in mind that Kindle is the first product in a new genre. Competitors are sure to introduce their own "improved" versions.

By the time we have pioneers on the lunar frontier, the Kindle will be remembered as a crude start, and you will be able to see one in the Luna City Museum. Kindle is a glimpse of things to come.

Here is the very long link:

http://www.amazon.com/gp/product/B000F173MA/ref=amb_link_6369712_3?pf_rd_m=ATVPDKIKX0DER&pf_rd_s=center-1&pf_rd_r=09NM5ARC30040T722137&pf_rd_t=101&pf_rd_p=441946601&pf_rd_i=507846

For the rest of you, a picture is worth a thousand words.



Product Description

“Three years in the making, Kindle™ is an entirely new class of device—a convenient, portable reading device with the ability to wirelessly download books, blogs, magazines, and newspapers.”

Paper-like Screen

“Utilizing a new high-resolution display technology called electronic paper, Kindle provides a crisp black-and-white screen that resembles the appearance and readability of printed paper. The screen works using ink, just like books and newspapers, but displays the ink particles electronically. It reflects light like ordinary paper and uses no backlighting, eliminating the glare associated with other electronic displays. As a result, Kindle can be read as easily in bright sunlight as in your living room.

Ergonomic Design

“At 10.3 ounces, Kindle is lighter and thinner than typical paperbacks, and fits easily in one hand. Its built-in memory stores hundreds of titles. An optional SD memory card lets you hold even more.

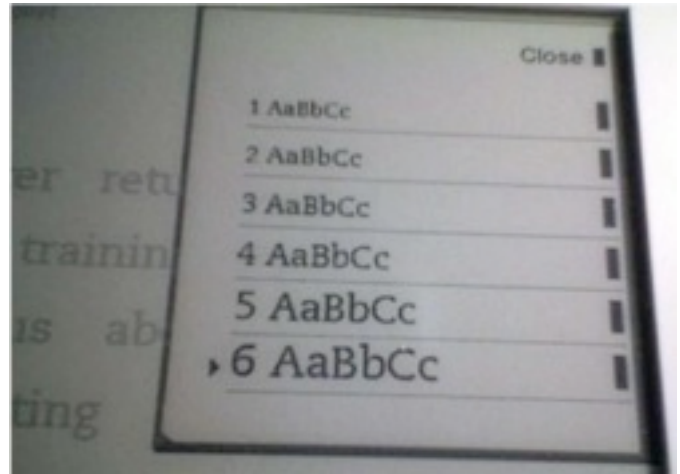
“We wanted Kindle to be as easy to hold and use as a book, so we designed it with long-form reading in mind. When reading for long periods of time, people naturally shift positions often. Kindle’s full-length, vertical page-turning buttons are located on either side, allowing you to read and turn pages comfortably from any position. Navigation on both sides means both lefties and righties” can easily use Kindle with one hand.

“You can be anywhere, think of a book, and get it in one minute. Paperback size and expandable memory let you travel light with your library. With the freedom to download what you want, when you want.”

More, and the bottom line

Kindle uses a long-life battery, comes with a USB cable and a protective cover. It stores “hundreds” of books at a time, even more with a memory card.

And it costs \$400. But we all know how introductory prices come down the minute a competitor surfaces. As always, if you have to be the first in your block to own something, you will pay a premium price. But as it costs only \$9.95 to download a whole book, it will soon pay for itself if you are an avid reader.



Oh, yes! It does something no conventional book can do. It let's you change the font size! (even the font??)

And, it is pencil thin



Looking ahead to the lunar frontier

While the product seems to be well-developed, it is of the nature of competition that new and improved features will be added. It may already display color photos, but how about embedded videos? Could you one day switch “channels” to a monitor view of sleeping children? It already includes Wikipedia, and a full-size, full-feature dictionary.

Will future models let you edit, write? It should be a small step to develop larger even flater versions to replace color posters and billboards.

Kindle-available books already include those in other languages. In the future will a new version translate them for you, giving you access to foreign as well as ancient libraries?

Substitutions for paper books is just the start. There are many other paper products and uses that will be a challenge to replace on the Moon. Do read our original article mentioned above for a long list of these and for our 21 year old proposed strategies.

Kindle is an example of developing a product needed on the Moon, because it was also needed on Earth as well, as we become more environmentally aware.

Back to the past

Oh yes, about that novel - I was still in the research stage (though I did have a plot and a developed list of key characters) when L5 Society members from the Chicago and Minnesota L5 chapters descended on a Science-Fiction Convention (Triangulum 2) in Milwaukee on August 15, 1986 to talk to invited local members. I was one of those, and when it came to choose officers, I preemptively volunteered to do a newsletter (intending to use the research already produced for the novel.) I decided to call it **Moon Miners' Manifesto**. MMM would take all my time and energies, and as you may have guessed, I never did finish that novel. *And now you know the rest of the story!* <MMM>

ART FROM MOONDUST

An idea for Public Art in Luna City

By Charles F. Radley charles@stratowave.com

Comments and discussions by several persons on artemis-list@asi.com edited by Peter Kokh

Colored sand art called "Mandala" is a sacred art form in Tantratic Buddhism. The monks of Tibet do this. Some beautiful photos on the wikipedia page:

<http://en.wikipedia.org/wiki/Mandala>

<http://community.berea.edu/galleryv/mandinfo.html>



From Wikipedia, *loc. cit.* "Chenrezig Sand Mandala created at the House of Commons of the United Kingdom on the occasion of the Dalai Lama's visit in May 2008

A mandala is sometimes called a "cosmogram", appropriate term for cosmos-exposed art on the lunar surface!

Would the Moon be a cool location to practice this.? It could be a bit difficult to craft the fine intricacies wearing a clumsy EVA suit, with stiff gloves. Maybe they will have to be created indoors, and wheeled out through an airlock. But the air movements during depressurization could disturb the sand particles. Air trapped between the sand particles would need to be gently vented. We may have to depress very slowly, over a few days, to avoid unwanted air currents and churning of the sand.

Out on the lunar surface, it is mostly micrometeoroids which would churn up the surface. Also, at the terminator, static electricity causes dust storms every dawn and dusk on the Moon. Would they erode any moondust surface art? How quickly?

It might be an interesting experiment to see how long a Mandala would endure.

Comments: From: Dale Amon amon@vnl.com

While reading some old MMM I was struck by an idea for city areas in vacuum. Since there is no wind or rain, if you spread colorful dust on to a surface it should stay for decades at least. It would slowly be turned over by the changing temperature day/night cycle, but even that could be dealt with by making the layer deeper or just tidying it up every 50 years or so.

Folks with truly bad taste could create a front lawn that looked just like an Elvis on Velvet painting... those with a bit more artistic taste might do something more of value. An industrial area might make the entire site into their logo as seen from above. A high rise lunar hotels could have an area around the base done as an artistic continuation of the hotel interior that creates a transition between hotel interior and lunar grey.

I'm sure kids would eventually find it fun to make changes, but a little bit of dust by the building maintenance folk in the morning would sort that out.

A spaceport could have the surrounding areas modified to act as landing approach aids. A simple concrete pad in the middle of nowhere might be difficult to spot. Some would say the computers will handle the landing so it does not matter... but pilots do like to fly their own craft or at least know that they can if something goes wrong.

I am sure there are materials that could provide bright colours. Titanium dust should be able to provide a lot of pastels. Peter has talked about a painter's palette in the past. How about a simple colored dust palette?

It's an art form little used on Earth because it can only be done at great expense with mosaic tiles. On the moon the artist just sprinkles the color onto the surface.

If you take the surface painting idea and include rocks as in some of Peter's lunar Zen garden ideas and then mix in junk sculptures made from odd bits of rockets and technological detritus, you may have the beginnings of a real formal garden art form.

There are such gardens in Mexico and the southwest where plants are merely one element of the palette. Then add in some of the old English Garden ideas with greco-roman buildings, grottoes, stone stair cases and meandering walk ways and view lines and you start to get really, really interesting. <DA>

Comments: From: Peter Kokh kokhmmm@aol.com

Now there are two approaches: near term options longer term options. Near term, we could collect regolith samples in various graytone ranges. (It would be difficult to sort moondust particles by color, but we could collect gross samples of different shades) Highland moondust is generally lightest Mare moondust is generally darker Ilmenite (titanium-iron oxide) rich moondust is perhaps the darkest Plus there are the "orangish" samples from old volcanic fire fountains

Once we begin processing, the easiest addition by far is ochre: Just take any moondust sample, steam it in a tumbler, and any iron fines will rust. Samples with highest iron content produce deepest color.

Isolating compounds: Calcium Oxide (Lime) & Titanium Dioxide are white (the latter being the basis of most white paints) Pure sulfur powder is a pale yellow Mixing rusted regolith with sulfur produces orange tones.

Chromium oxide is green (isolate chromium first, that's the catch.) Cobaltous Aluminate is the most perfect stunning blue (isolate the cobalt first, that's the catch.) Manganese Dioxide is black (must isolate the manganese.)

You can get shades (towards the black) and tints (towards the white) by mixing with manganese dioxide (or titanium oxide) and calcium. Rusted regolith plus calcium oxide produces pinks. By and large we are dealing with metal oxide pigments.

There does not seem to be a close good red without lead, which is only present in parts per billion, so ochre & rust are as good as we are going to get. Sulfur pale yellow was the best I could do in the yellow area.

Mixing sulfur or lime with chromium oxide green gives a whole family of greens. Could try mixing chromium oxide with cobaltous aluminate to get aqua and turquoise. *These powders are going to be expensive to produce early on, so we will want to dust them on the surface rather than mix them in for best effect.* <PK>

LUNAR ENTERPRISES AND DEVELOPMENT

Especially prepared for *Moon Miners Manifesto*.

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Installment 4

EXHIBIT 9 – Lunar Industrialization



Exhibit 9 – Lunar Industrialization: Entrepreneurs will discover a variety of commercial endeavors to pursue on the Moon, from building lunar structures and facilities, to mining and manufacturing, to providing goods and services almost beyond our present imagination. * *Source*: NASA Headquarters.

2. Lunar Administration & Governance

Moving humanity beyond Earth raises serious issues relative to leadership and organization in outer space. These go beyond mere matters of science, technology, legality, and finances. This “giant leap for humankind” is altering the species, especially in terms of biological and cognitive adaptability. Within that context, we may then consider space policies, settlement, and commerce. Governance, especially of space settlements, will shape human futures into an extraterrestrial civilization. Thus thinks Professor Yehezkel Dror, a policy planner and governance expert. As an astute social scientist, he observed: 22

The repercussions of moving into space are largely inconceivable, and efforts to predict them on the basis of a very different past are extremely doubtful. Therefore, applying NASA’s experience beyond some technologies to the problem of building a future for women and men beyond Earth offers a much too conservative perspective. Similarly cost-benefit analysis in terms of contemporary economic realities misses the implications of settling human beings outside of Earth on all aspects of thinking and living, individually and collectively. Hence, new social structures are needed, with novel core capacities meeting the requirements of moving humanity into space. This is all the more crucial because space settlement is only one of the extreme changes that add up to a radically novel epoch into which humanity as a whole is inexorably moving, with tremendous potential for better or worse!

Among the characteristics of space governance, Dror suggests that it be

(1) **Global** in scope requiring cooperation among spacefaring nations;

(2) **Inspirational**, with the seeking of knowledge, the search for the new and unknown, the education of the masses as to the necessity of going offworld;

(3) **Long term perspective and persistent**, that requires radically different governance systems which are as democratic as possible;

(4) **Planned in terms of mega-project resources and management**, that may involve generations and innovative methods of financing, as well as learning;

(5) **Positive re-enforcement tools** which allow for human cultural differences, frailties, and abuses, but maintains civilized standards;

(6) **Cognitive abilities in leaders** who are competent in managing large-scale enterprises;

(7) **New rationale that espouses positive, demo-cratic values** for the long-term benefit of humanity and the common good. This will necessitate creating new lunar institutions, leaders, and professionals!

2.1 Background Observations

Previous multinational negotiations relative to United Nations space treaties have recognized the need for some type of international regime to deal with the exploration and development on the Moon. No nation has yet offered a specific proposal as to what this entity might be and do. Some scholars have referred to the possibility of duplicating the Antarctica model in which various countries entered in an international agreement as to their operations in that remote region. Thus, various national outposts or bases were established there, primarily for the purpose of exploration and science. However, under that arrangement, some significant science has been achieved, but little development of the areas resources or population.

Dissatisfied with provisions in the Moon Treaty, which most spacefaring nations have not signed, the space law community would prefer to have the nations actually engaged in lunar enterprises confer and agree on some legal and regulatory institution that would facilitate cooperative lunar development within the global space community.

Various specialists familiar with the challenge have offered thoughtful solutions to this need which becomes more pressing as space agencies from Canada, China, Europe, India, Japan, Russia, and the United States move ahead on a series of lunar missions, culminating in the placement of humans back on the Moon to stay. Until lunar governance and legal matters are resolved, public-private partnerships, venture capital and private equity financing, will be restrained in promoting lunar commercial enterprises.

Legally we need transnational answers to basic questions, such as proprietary rights relative to lunar resources, including who may sell or profit from such; who may issue licenses or permits for lunar mining and other business activities, One possible model suggested by Sadeh, Benaroya, Livingston, and Matula is the U. S. Deep Seabed Hard Minerals Resource Act of 1980. 23 This American Federal legislation establishes an interim regime that provides legal protection of U.S. firms, pending an international agreement on deep-sea mining

and resource activities. The professors argue that comparable legislation for lunar commerce is needed until international agreement on lunar resources is achieved. For the latter, these four authors offer an interesting analysis of three possible solutions (government, business, and technology models). Then these scholars suggest that dual-use technology deals with lunar projects and technological developments that are so expensive, long-term and large-scale, they require substructuring of the macro venture into smaller and profitable, independent units. To that end, they recommend formation of a Lunar Development Corporation, seemingly modelled somewhat after LEDA which will be discussed in the next section. This public corporation would include teams of management scientists and engineers, finance. Legal and other experts, LDC would ensure that the right technologies, materials, and workers are available when needed to successfully complete lunar projects.

In a previously cited book, *Return to the Moon*, former U. S. Senator and *Apollo* astronaut, Harrison Schmitt devoted a chapter to "Law: Space Resources." Here the last man on the Moon examines relevant laws and precedents as applied to lunar development. He concludes that the present situation is fraught with serious impact on the private entity's ability to maintain space operations, especially as related to safety concerns with its personnel, access to capital and customer makes on which business is so dependent. Unfortunately, this knowledgeable scientist, and statesman offers no recommendation as to what kind of international regimen might solve the problems of lunar enterprise.

Sometimes, professional article articles and science fiction precede space realities, giving us insights for future decisions. 24 For example, in his writings, Krafft Ehrlicke, laid out a detailed plan for creating a polyglobal civilization, including a lunar city called *Selenopolis*...

In his book, *Welcome to Moonbase*, Ben Bova made a persuasive case on how to establish lunar bases and how to manage as dual economy there with Earth. His scenario envisioned two bases, one founded by Russia on *Mare Nubrium* and another by the United States on *Mare Vaorum*. The latter's development is illustrated for the period 2015-2018, remarkably similar to what is now underway under the *VSE* plan. It would be operated by Moonbase Inc., made up of stockholders from 15 nations, plus large multicultural corporations.

Phil Harris' *Launch Out*, offered a science-based scenario for space enterprise, lunar industrialization, and settlement. His 2010 prognosis for *Selenians* living and working in a future LUNAR WORLD, made up of several areas at the start: a Krafft Ehrlicke Lunar Industrial Park, the Konstantin Tsiolokovsky Educational and Research Center, the under-ground multicultural living communities of Eastasia and Euroamer, as well as the Gerard O'Neill Health and Wellness Center and the Carl Sagan Astronomical Institute.

This macroproject on the Moon would be under the administration of a GLOBAL SPACE TRUST, guided by a civilian, democratic management council of multi-disciplinary experts who adhered to the *Declaration of Interdependence for Governance of Space Societies*. The GST Fund to under-write these costs for an eventual lunar population of 2,000 would include contributions

from both the world's public and private sectors. Further financing would come from the sale of GST/LEDA bonds and an international lottery. In addition to its own spaceport, the Trust would operate four ground-based facilities and services for those in orbit transportation, communication, and supply bases, plus the Unispace Academy located in Hawaii near the East-West Center there, for the training and preparation of all GST spacefarers. All stages of this undertaking on the Moon would be coordinated through a Lunar Economic Development Authority as described next.

2.2 Lunar Economic Development Authority (LEDA) Proposal 25

To meet the need for an interim regime to develop a twin Earth-Moon economy, the co-founders of United Societies in Space conceived a strategy based on an existing model - the Tennessee Valley Authority and the many port authorities around the world. The entity was called the Lunar Economic Development Authority, and could be a quasi public or private, or combined corporation.²⁵

For those objecting to the term, "authority," other words could be substituted, such as corporation, council, or foundation. The point is that the global community would create a centralized institution, whether in conjunction with the United Nations or not, to coordinate humanity's activities on the Moon, thus avoiding overlapping efforts and expenditures. Here are some of the services that LEDA might provide;

- (a) Issue bonds to underwrite lunar enterprises, including a transportation system, a base and an industrial park ...
- (b) Lease surface and mining rights for private or public sector lunar macroprojects and collect fees there from ...
- (c) Coordinate and facilitate international endeavors by space agencies, scientific organizations, and private corporations on the Moon or its vicinity ...
- (d) Provide a lunar administrative structure for oversight supervision of terrestrially sponsored undertakings and communities on the Moon, so as to protect the environment and interests of its owners, humanity ...
- (e) Contract and supervise necessary infrastructure provisions, such as a **lunar transportation system**, a **lunar power system**, and a **lunar personnel deployment system** ...
- (f) Operate a lunar spaceport for all users, possibly with a landing fee to support infrastructure development...
- (g) Act as a clearinghouse of data about lunar information, such as conditions, resources, sites, and programs for future investors, project sponsors, and settlers ...
- (h) Conduct public information, outreach, and development programs on Earth to encourage investments in lunar resource utilization and lunar resettlement.

Rather than depending on the home planet's taxpayers to finance construction of lunar infrastructure, LEDA would underwrite such development through income-producing activities such as outlined above, or by contracting with the world's financial systems for loans, et al On Earth, ships and airplanes pay for the

privilege of sailing or flying into urban ports; it would seem reasonable, then, that spacecraft from both public and private sectors worldwide might also be charged a fee someday by the LEDA for the privilege of landing on the Moon. When tourism reaches the lunar surface, such fees could contribute significantly to the lunar economy.

Right now for development purposes, there is no legal or financial mechanism, no less technological infrastructure, for such interplanetary undertakings that provide transnational, global participation. Even those who drafted the 1979 Moon "Treaty" envisioned some type of outer space regime or **authority** to oversee and regulate the "orderly development and exploitation" of extraterrestrial resources. Writing in 1994 on "Lunar Industrialization," Prof. Haym Benaroya of Rutgers University forecasted that such commercialism could employ 3–12% of our population in new jobs, both on the ground and aloft! 26 But he too foresaw the need for some type of Space or Lunar Industrialization Board (but within the U.S. government) to set policy, as well as coordinate and oversee economic, legal, and technical aspects of resource development on the Moon, and later Mars. In that same year, Lubos Perek, a former chief of the UN Outer Space Affairs Division, made a significant case for improving the management of outer space activities. He argued that to manage extraterrestrial resources, a UN International Space Centre (UNISC) needed to be formulated.

Dr. Nathan Goldman: a Houston attorney and author of *American Space Law*, commented: 27

The Lunar Economic Development Authority, similarly, will be structured to create an international regime that would encourage, as well as regulate, (rationalize) the habitation and commerce on the Moon. The LEDA fills in the blanks of incomplete space law with details that can make space available for human development in a very short time.

More recently, Dr George S. Robinson, former associate counsel of the Smithsonian Institution, called for a Declaration of Interdependence between Earthkind and Spacekind, perhaps establishing an International Organization for Spacekind Cultures (IOSC—refer to Appendix A). This space law scholar sees as its purposes to: 28

- (1) Provide an interdisciplinary, international, and trans-national body of recognized experts to continuously review interactive relationships between Earth dwellers and spacefarers ...
- (2) Grant international agreements of recognitions and capacity (IARCS) to those space communities that satisfy the requisites for home rule as set by IOSC or something comparable (such as, the proposal of United Societies in Space to found a space Metanation, possibly under UN auspices) ...
- (3) refer case situations of conflict to the International Court of Justice, or a transnational court yet to be founded for this purpose.

The above citations underscore the growing consensus that utilization and development of space resources require creation of a new entity to coordinate global space enterprise and governance, whether within or outside the existing United Nations. 29

Certainly, some institution has to be devised to foster lunar development, preferably one which in scope

goes beyond governments sponsorship or even a combination of national space agencies. A **Lunar Economic Development Authority** should be intersectoral, representing the interests of public and private sectors on a planetary scale. It should encourage participation of transnational consortia, whether from universities, corporations, space associations, or agencies. The macrothinking here should go beyond the European Space Agency proposal for an International Lunar Quinquennium meeting every five years to discuss lunar projects (refer to section 7.2.2).

In conclusion, the UN's Outer Space Treaty was ratified by some 90 nations. Today, few states or their commercial entities would seriously consider participating in a venture which was not perceived in accordance with the international agreement. Before returning to the Moon by 2020 under the *Vision for Space Exploration* plan, **it is essential for some accord among space agencies and private enterprise as to how we are going to proceed there for the benefit of humanity as a whole.** At least, LEDA is a proposal to spur discussion until some formal concurrence is achieved within the next ten years. 30

2.4 *The Strategy of Space Authorities*

Although the writer believes that to further human enterprise in space, a viable solution to this challenge is to establish **space authorities**, now for the Moon, and eventually for Mars, and other planets, as well as for stations and platforms in orbit, even asteroids. It is a way to use our "interplay-netary common" for the benefit of Earthkind in the 21st Century. 31 Then, we would put institutions in place to empower scientists, engineers, entrepreneurs, or settlers to go aloft and utilize space resources. To facilitate living and working in isolated, confined, sensitive environments, like the Moon, the legal and governance prototypes already exist.

For example, the Antarctic Treaty (1958–1961), with its protocols and organizations, as well as the Tennessee Valley Authority. The Antarctic Treaty provides the legal framework for the area south of 60 degrees south latitude on this planet, reserving the region for peaceful purposes and encouraging international cooperation in scientific research there. The other model is the T.V.A., authorized by the U.S. Congress in 1947 with a Board of Governors appointed by the President and confirmed by the U.S. Senate. When it was founded, the United States Government not only donated land and facilities for the new entity, but vested enough sovereignty in the T.V.A. so that it might obtain more land, including by eminent domain. The Authority's objectives were to conserve assets for the benefit of the American public in general, and specifically to provide electric power for the benefit of the people in the region served. To achieve its objectives, in 1948, T.V.A. issued \$50,000,000 (U.S.) worth of bonds @ 3.2% interest rate, secured by a blanket debenture of its assets. Thirty years later these debentures were retired with no defaults, rollovers, or commissions having been paid. Today, the T.V.A. is one of the largest, most successful power producers in the world, a strategy worth emulating if resources on the space frontier are to be transformed for the betterment of the people of "Spaceship Earth."

This type of quasi-governmental **service authority** is a proven, respected, and traditional venue for underwriting and managing both public and private

undertakings across jurisdictions and borders. It has been gainfully used to construct terrestrial infrastructure from air and seaports, to building bridges, toll roads and convention centers. Port authorities have been successfully constituted across the U. S. A., from New York to San Diego. The New York Port Authority, for instance, crosses state lines to serve a metropolitan area's transportation needs. NYPA has its internal police force, which can arrest those who fail to comply with state, local, and Authority regulations. The approach is justified because of the size, value, and complexity of port facilities relating to transportation, safety, docking, food spoilage, longshore personnel traditions, and union contracts. The new Denver International Airport Authority was also financed by Municipal Airport Revenue Bonds totalling \$275,000,000, but these were government guaranteed.

Spaceport Authorities are another example of the same strategy in use internationally from Florida to Australia. Why not adopt a comparable mechanism to finance and promote a **space infrastructure**, which might supplement or replace direct taxation for space exploration and commerce? ... An interesting historical point is that the U. S. Federal Statutes authorizing the inauguration of the U.S. space program, began with a section on Police Authority (42 U.S.C. 2456) with the power for personnel to arrest citizens and bear arms for that purpose; that statute also created the agency that eventually became the National Aeronautics and Space Administration.

Thus, legal precedent exists and might be tested for application in space by the immediate incorporation of a global **Lunar Economic Development Authority**, whether this be accomplished by private enterprise, government, or a combination thereof; whether it be within or without the United Nations, whether it be under national or international law. Should LEDA prove to be successful prototype, then it might be replicated next by the establishment of a **Mars Economic Development Authority (MEDA)**, and the model eventually repeated for the development of orbital stations or cities, other planets or asteroids in our solar system.

There are various scenarios as to how such **space authorities** might come into being within a decade:

- (1) Assuming a **Lunar Economic Development Authority** is the prototype, incorporate it in one or more states or nations. Thus, profit and/or non-profit organizations might combine their strengths to undertake macroprojects on the Moon. There is ample precedent for this among world corporations and foundations seeking to protect the global commons. One scenario is the U.S. Congress provides legislation constituting a **Lunar Economic Development Authority**, essentially to conserve national interests and promote development of the Moon and its resources for the benefit of its citizenry and to cooperate with other nations in this goal. The charter might be similar to that of T.V.A., and possibly some existing space assets might be transferred from NASA or DOD to the new Authority to provide security for the lunar bonds sold for investments on the Moon. **LEDA**, in turn, might legally contract for services from NASA or other federal and state agencies, or from universities and corporation in the private sector at home or abroad.

The Communication Satellite Act of 1962 is another precedent for such action, for it established COMSAT to cooperate with other countries to develop an operational satellite system, as well as to provide services on a global scale to others. Given the trend toward "privatization" of public properties, imagine if the assets turned over by the Congress to the new lunar Authority were to be two spaceports now functioning at Cape Canaveral in Florida and Vandenburg AFB in California; both built and paid for by taxpayers could then produce bond revenue and other income flows if operated by **LEDA**!

- (2) Another scenario would form a consortium by spacefaring nations committed to lunar enterprise who sign an international agreement to establish a **Lunar Economic Development Authority**. In this approach, **LEDA** acts on behalf of the participating countries in financing and macromanaging resources on the Moon. The precedent for this already also exists in such agreements as **INTELSAT**, which established a global satellite communication system signed by governments or their designated public or private telecommunications entities.
- (3) Although any of the above solutions might precipitate desired action toward near-term lunar development, many prefer a strategy whereby spacefaring nations work through the United Nations to found **LEDA**. At the very least, the U.N. would be the logical organization to call a summit conference of spacefaring nations in an attempt to achieve some international consensus on this important matter of humanity's moving offworld!

Admittedly, the Outer Space Treaty implies that nations which place their citizens into space, such as on the Moon, have a responsibility to exercise some form of control over them. That is relatively easy with a few government-sponsored astronauts living in facilities provided to them by that entity. But what happens with settlers who are many decades in orbit? Further, how can this control be exercised when private citizens gain access to low-cost spacecraft and begin to migrate on their own in ever larger numbers to the lunar surface? It would appear the relevance of this forty-year old Treaty will diminish. Better to have a global consensus and legal provisions in place before the masses move to the Moon and beyond.

The purpose of this Corporation (Lunar Economic Development Authority) shall be to promote the Moon as a place to live and work as a society of peoples and to help create and maintain a consensus governance authority at the venue of the Moon, including its useable orbits, and to educate people on the benefits, burdens, and responsibilities of living and working in space. The Corporation will serve as the agent of humankind in space and at the Moon, as well as the agent for all of the sponsor nations, to develop the Moon for humankind. It is the intended business of the Authority to administer each nation's rights under the *1967 Outer Space Treaty*

---Article III, Articles of Incorporation for the Lunar Economic Development Authority, Inc.

Interestingly, a space policy analyst *Washington Dispatch*, Mark Whittington, has written that a **Lunar Exploration and Development Authority** would be helpful in opening up the high frontier. 32 This

proposed LEAD has the emphasis on exploration, not economic development as does the above LEDA. He considers such a worthwhile mechanism for carrying out White House Space Transportation Policy (STP). The Administration's committee examining ways to implement its *Vision for Space Exploration* is chaired by an Admiral Craig Steidle. That group is concerned about how to "open space enterprise, markets, and ultimately self-supporting activities," which is also the purpose of this LEAD proposal. This strategy, like the other LEDA, is to encourage commercial development on the Moon, and through that improve the Earth's economy. STP states the government will refrain from activities that have commercial applications, so as to involve the private sector in the design and development of space transportation systems. Whittington maintains that his LEAD offers an innovative way to explore space, one using entrepreneurial and commercial strength of private enterprise.

In that same issue of *Lunar Enterprise Daily*, Anatoly Perminov, head of Russia's Roskosmos, has written that to explore Mars with humans, there must be an *International Space Station* and a Moon base. According to *RIA Novosti*, he believes that *ISS* provides the laboratory for long-duration, microgravity training, and the Moon for Martian environmental simulation studies. He envisions *ISS* as a spaceport for lunar bound spacecraft (<http://rian.ru>).

2.5 Creating Lunar Social Systems

Dr. Ben Finney, when a sociologist at the University of Hawaii, contributed to the NASA publication on *Space Resources*, previously cited in this book (SP.509, 1992). His theme was "Planning for Lunar Base Living," but his perspective was that of the social sciences and systems – that is, creation of a human community on the Moon. Perhaps this quotation best summarizes his thesis:

But going back to the Moon presents a social, as well as a technical challenge.

As Krafft Ehrlicke well recognized, in addition to developing low cost spaceflight, methods for processing lunar and other space materials to manufacture, safe and ecologically sound habitats, we also must develop systems of social organization for living in space. The experience of small, isolated groups in highly stressed environments points to the need for developing social systems that will enable people to live and work productively in space. The composition, organization and governance of the first lunar communities will be vital to their success, and ultimately to realising the goal of living permanently in space. We need to start now on a research program directed to developing social systems designed so that people can live safely and productively on the Moon.

That is exactly what Dr. James Grier Miller proposed in applying living systems theory to humanity offworld (refer back to chapter 3.6). Finney, co-editor of *Interstellar Migration and the Human Experience*, cited in our second chapter, offered five recommendations relative to establishing a lunar community of diverse spacefarers:

- Use an integrative approach of living systems, one that is multidisciplinary and combines both biological and social science research...

- Make this planning of an appropriate lunar social system part of a larger iterative program of learning how to live beyond Earth, whether in orbit, on the Moon or Mars, and other celestial bodies...
- Conduct realistic simulations and experiments of space social systems before they are put into operation aloft...
- Include self-designed plans by those who actually will have to live on the lunar surface – encourage them to be active participants in this R & D ...
- Facilitate planning for lunar community autonomy – while at the start, the lunar dwellers will be very dependent on earthkind for materials, supplies, and equipment, encourage local initiative, especially in the innovative utilization of lunar resources and creation of a culture that is appropriate to the environment and situation up on the Moon. (For instance, NASA has already designed software tools called *SpaceNet* for supplying and tracking needed inventory on the lunar surface, so that the astronauts there will know when to request necessities for re-supply.)
- Less and less control and monitoring of the explorers should be exercised, so they become more independent and responsible for their own well being offworld. As their communities mature, grow in size and competence, spacekind should be encouraged to develop their own solutions and enterprises. One example, is the matter of rules, regulations, and laws – the less such is imposed on these pioneers, the better so they can formulate a governance system appropriate to their experience (e.g., that is how *astrolaw* will emerge). Actually, the goal is to cultivate interdependence between earthkind and spacekind.

3 LUNAR EXPLORATION AND SCIENCE

Human nature is to explore – our mammal ancestors began to do so between 100 and 85 million years back in time, long before the asteroid arrived some 65m years ago. Explore means traveling to an unknown or an unfamiliar place or region for the purposes of discovery. Certainly, that definition fits the seventeen *Apollo* missions, and what is being now undertaken to implement the VSE policy to return to the Moon permanently. In the past exploration was undertaken by adventurers, scientists, navigators, and even the military to establish jurisdiction over a territory. Lunar exploration, however, will be lead first by engineers, scientists, and technologists until such time as all those "others" follow.

Given the circumstances of the Moon, lunar explorers will have to be knowledgeable, experts in several fields. Lunar exploration is planetary in scale, seeking information not only about our Solar System, but also the composition and history of our own Earth. Exploration on the Moon is a high technology investment that should produce multiple benefits for humanity. It will affect the aspirations, education, and motivations of future generations of today's youth, ultimately will involve everyone on the home planet. But the considerable expense and risks in lunar activities demand international cooperation on a level never achieved before in the human family.

The Moon is a natural laboratory of some 38 million kilometers. Study of its geological processes will help us better understand both our Sun, and our Solar System, their evolution and that of our twin sister planet.

As our closest and most reach-able neighbor in the universe, the Moon is a test bed for learning new skills and developing new technologies. It is an orbital platform for Earth observation, offering scientists an ideal location for projects in exobiology and radiation biology, lunar ecology and environment, and eventually human physiology and psychology in an isolated, confining environment.

It is also a place for electromagnetic and ionising radiation, and to investigate their biological importance in cosmic and solar radiation. To protect lunar dwellers, it means inventing radiation monitoring, shielding, and solar-flare shelters, as well as health monitoring systems. It also means dealing with moon-dust, composed of half silicon dioxide (rich glass bombarded by meteorites, with the rest mainly iron, calcium, magnesium, olivine, and pyroxene). *Apollo* astronauts reported this fine dust covered their spacesuits and seemed to smell like "gun powder."

Then there are moonquakes – possibly tidal in origin and some 700 km below the lunar surface; vibrations from meteorite impacts, thermal quakes from the expansion of frigid lunar crust; shallow moonquakes up to 30 km below the lunar surface.

Ah yes, the challenge of living and working on the Moon demands careful synchronization of scientific, technical, robotic, and human capabilities. The facilitating of synergy among lunar explorers may prove to be our hardest task to accomplish there! But it also an opportunity to live in a world of our own peaceful creation!

3.1 The Antarctica Model vs. Terraforming

Presently, there is an international agreement for multinational bases on that continent for the purpose of scientific research. 33 Forty-five Antarctica signatories agreed to suspend territorial claims and disputes there, to forego all military and mining activity, to protect the environment, and to preserve the continent as a "natural reserve, devoted to peace and science." That experience does provide an analog for humans who will be living and working on the Moon in a somewhat comparable circumstances. 34

Similarly, scientists from one country may wish to establish research outposts on the Moon as they do now in Antarctica. Currently at the latter's South Pole Station, the United States has built a new habitat with many amenities for 200 occupants. Only about 1,000 people live in this remote land year round, adding another 3,000 during the summer when the weather improves. But while some worthwhile scientific knowledge has been gained under that model, there has been no economic development on that remote, icy continent for the past fifty years! With climate change concerns, some 60 countries are finally planning to spend some \$1.5 billion there, plus 10,000 researchers will visit during this International Polar Year of 2007. Space technology benefits Antarctica in some ways beyond mobile phones – such as GRACE, or the Gravity Recovery and Climate Experiment which measure minute changes in the Earth's gravity produced by thickening and thinning of the ice sheets.. Yet, the Moon, like Antarctica, might hold the future to life on Earth and possibly beyond.

Humanity wants to do more than science and astronomy on the Moon – we want to industrialize and

settle that planet, and use it as a launch pad into the universe. We hope to use the Moon as the first planet for terraforming. 35 As Martyn Fogg explained, our goal should be to engineer planetary environments for the better. This British author argues that alien worlds can be transformed by humans into human-habitable planets, like Earth. That is why Carl Sagan proposed to terraform the planet Venus. Thus, the Moon can become a terraforming laboratory for Mars and beyond. There are terraforming expertise to be acquired on and under the lunar surface, as we alter the Moon to suit living creatures, but with due regard to preservation of its environmental integrity. New technology applications will have to be created in terms of closed-environment and life-support, plus uncover ways to use local resources to provide sufficient water, power, and communications.

On the 50th anniversary of the first landing on the Moon by our species, 2019 might be an appropriate time to announce the **International Lunar Year of 2019!**

3.2 Science Role in Lunar Exploration

John Connolly of NASA's Johnson Space Center has said, *We are going back to the Moon to relearn the art of exploration.* In that same article, NASA's Ames Research Center scientist, Chris McKay gave his reasons for science to be involved in that process: 36

- _ Science is needed to provide data to make human exploration safer;
- _ The *Vision for Space Exploration* needs to be science driven and the science community should shape the lunar choices;
- _ Before humans arrive back on the Moon, robotic missions should precede them, especially to collect scientific data and measurements are needed, especially about topography;
- _ Robots can provide vital information about lunar hazards, ice, vacuum.

This distinguished planetary scientist seeks a well-connected, well-developed lunar science community that achieves some consensus now in setting forth the science agenda for the Moon. Others, such as engineers, might counter that their knowledge and skills should be given priority. In any event, to succeed within that huge lunar learning laboratory, a multidisciplinary approach will be needed. It will be a combination of many fields of knowledge and skill that will enable lunar settlement by people. The Moon is for more than a place for astrobiology, astrophysics, and astronomy! Assuredly, behavioural scientists and health care experts life science and habitation research will play a critical role in human survival. So will those innovator who develop instruments, like micro-dosimeters whose sensors measure radiation energy in individual blood cells, thus detecting harmful levels of radiation that may endanger its human population. Scientists at ASRC Aerospace Corporation in the Kennedy Space Center are studying a billion-like electromagnetic shield that would form a protective force field around a habitat. They propose 5-meter inflatable spheres made of strong fabric and coated with a conductor to repel positively and negatively charged ions contained in cosmic and solar radiation, especially dangerous during swift solar storms.

In August 2007, NASA announced these science projects as part of its *VSE* plans ("Astrophysics-Hitching to the Moon, *The Economist*, August 11th, 2007, p 73):

- 1) Placing a radio telescope on the far side of the Moon to examine the early universe, including the study of large-scale structures, such as galaxies and stars. Such a lunar-based telescope could detect long wavelengths that cannot be observed on Earth because of atmospheric absorption. This device might prove useful to detect extraterrestrial life, to map the stars and exoplanets that circle the stars, and to engage in studies that are almost unimaginable today. Joseph Lazio of the U. S. Office of Naval Research proposes an array of three telescopes, each 500 metres long, whose Y-shaped arms would be covered plastic film and could be rolled out on the surface of the Moon...
- 2) Examination of solar winds, a stream of charged particles ejected from the Sun which interacts with the tenuous lunar atmosphere close to the Moon's surface. Headed by Michael Collier of the NASA Goddard Space Flights Center, the study will analyse the resulting bombardment, and the low energy x-rays it produces on the lunar surface.
- 3) Wider dispersion of new, more sophisticated lunar reflectors beyond those dropped on the Moon previously by *Apollo* and the Russian *Luna* missions which are clustered around the lunar equator. Such reflectors are used in geophysics and geodesy (e.g., to research how the Moon's gravitational fields shift of time). Now Stephen Merkowitz of Goddard and Douglas Currie of the University of Maryland want to put improved reflectors spread over the Moon.

No wonder ILEWG has begun to award the "Young Explorers Prize" to innovative youth engaged in space science research (www.esa.int or www.katysat.org/)! And then there are those, like SETI and the National Institute for Discovery Science, who hope lunar exploration will advance the search for extraterrestrial life (www.access.nv.com/nids, or EM: nidstaff@anv.net).

EXHIBIT 10 *LUNAR SHELTERS



Lunar Shelters. After human return to the Moon permanently, the strategy is not only to build more than one base, but to have the lunar surface dotted with scientific instruments and facilities to carry out science and commerce. On its 38 million km, there will be small life support, communication, and equipment storage stations or refuges, possibly like the one depicted above. *Source:* NASA /John Frassanito Associates..

4. Lunar Settlement & Industrialization

Lunar enterprise will reach the Moon through contractors who will build the initial infrastructure there for science, settlement, and industrialization. Some of these "technauts" and their robots will be sent by big aerospace corporations, and others by start-up

companies, like Bigelow Aerospace with their inflatable buildings. As a case in point, consider the matter of constructing a lunar base, such as the one depicted in Exhibit 3. This was a proposal of Lockheed Missiles & Space Company, Inc., in cooperation with Bechtel and Science Applications International Corporation. The artist's conception is based on assumptions that it will serve as a permanent center for scientific, industrial, and mining operations. Capable of expansion, the first stage begins as a lunar outpost with the following features:

- _ Living, working, and recreational facilities to support a crew ranging from 20 to 30 people.
- _ Greenhouses designed to recycle life-support air and water supplies while supplementing food requirements.
- _ Shielded plant growth facilities to assure an adequate seedling population for the greenhouses if a crop fails.
- _ Utility workshops that enable technicians to repair and maintain equipment in a shirt-sleeves environment.
- _ Burial of the outpost or base in lunar soil for added protection against hazardous solar-flare radiation.

This is an example of innovative, macroengineering planning for early 21st century lunar development by three private corporations ahead of the curve. Now consider answers to these practical questions:

- (a) Who would operate and pay for the lunar transportation system to get to and from the Moon?
- (b) Who is the customer/s and how is this huge enterprise going to be paid for?
- (c) Under whose authority is this base to be built? That is, assuming the proponents could raise the money for this endeavor, how do private companies get international permission to use the Moon for this purpose?
- (d) If and when such an outpost and/or base became functional, whether it is by private or public or combined initiative, who or what supervises or manages this operation?

In trying to answer these critical questions, remember that under existing space treaties, the U.S.A. and NASA on its own would not seem to have the power to authorize, or even to contract for such development. Right now, Article II of the UN's Outer Space Treaty (1967) would seem to preclude it:

Outer space, including the Moon and other Celestial Bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.

Former astronaut and U.S. Senator, Harrison H. Schmitt, has written: *The mandate of an international regime would complicate private commercial development of lunar efforts. The Moon Treaty is not needed to further the development and use of lunar resources for the benefit of humankind - including the extraction of lunar helium-3 for terrestrial fusion power.* Now chairing NASA's Advisory Council, there would be many space lawyers who would challenge that scientist's Interpretation, particularly with reference to the original Outer Space Treaty. (Refer back to chapter 9.4.)

For decades, NASA has invested in numerous conferences on lunar activities and facilities, and published many documents on the subject with detailed plans. For example, a classic written in 1979 under the

direction of Dr. Gerard K. O'Neil was *Space Resources and Space Settlements* (SP-428). Then in 1985, its Lunar and Planetary Institute released, *Lunar Bases and Space Activities in the 21st Century* edited by Dr. W. W. Mendell. In 1988, the Office of Exploration sent another annual report to the NASA Administrator, *Beyond Earth's Boundaries - Human Exploration of the Solar System in the 21st Century*.

Again in 1992, the Agency issued five volumes entitled *Space Resources* (SP-509) centered on strategic planning for a lunar base, edited by Drs. Mary Fae and David S. McKay with Michael B. Duke. Then in 1996, NASA issued Technical Memorandum 4747 on *Lunar Limb Observatory - An Incremental Plan for Utilization, Exploration, and Settlement of the Moon* authored by Paul D. Lowman of its Goddard Space Flight. These are all remarkable and valuable documentation representing extensive scholarly research by aeronautical experts. The last mentioned provides unique insights on five stages of lunar exploration:

- (1) Site selection and certification;
- (2) Emplacement of a robotic lunar observatory;
- (3) Opposite limb missions or seven automated launch and observation missions to various locations on the lunar surface;
- (4) Lunar base establishment.;
- (5) Permanent human settlement on the Moon.

Such lunar historical publications should be the basis of all current strategic planning about returning to the Moon in the next decade by both the public and private sectors. But how many present NASA engineers and scientists engaged in planning to implement the *Vision of Space Exploration* are even familiar with such research? Do we ignore history as we reinvent the wheel?

In January 2007, NASA held a press conference on its preliminary lunar base plans, so as to insure crew survival and reusability. The main strategy seemingly will be to pick a primary base site, and then plan for sending to the Moon both cargo and manned missions in the next decade. Lunar experts favoring the South Pole location, Paul Lowman, David Schunk, and others urge Malapert Mountain as this site over the alternative, Shackleton Crater. The exploration emphasis will be on crew safety, both in vehicles and backup spacecraft for rescue missions, if necessary. For astronauts return to the lunar surface to stay in an environment without atmosphere, these are some of detailed matters being worked on today by lunar strategists and designers:

- Designing a less costly, space transportation system of reusable spacecraft, capable of launching large payloads to the Moon and back on a regular schedule...
- Building a lunar spaceport near the outpost site for landing and liftoffs
- Sequence, type, and storage of cargo from an autonomous lander before humans actually arrive....
- Unloading procedures and equipment (e.g., a crane) to remove cargo from the landers...
- Excavation equipment to dig holes and cover the "hab" units with protective shielding...
- Developing cryogenic propellant depots for lunar surface, orbit, and LEO...
- Designing lunar-based power and energy systems...

- Designing various infrastructure for the Moon, possibly inflatables, such as storage warehouses...
- Creating a lunar transportation system to move personnel, equipment, propellant, et al.

And this is just a sampling of the type of planning that has to go into a macroproject of this scope! No wonder one newspaper editorial called it "the costly frontier" - yes, it will be expensive until the return on this huge investment begins to be realized. (Check out this website: www.lunarbase.rutgers.edu/index.php.)

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In next month's issue of *Moon Miners' Manifesto*, MMM #221, we will conclude this paper by Phillip Harris, written specifically for publication in this newsletter.

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

**"Until you and I can buy a ticket to go
there, 'we' haven't got there yet."**

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