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

Moon Miners' Manifesto

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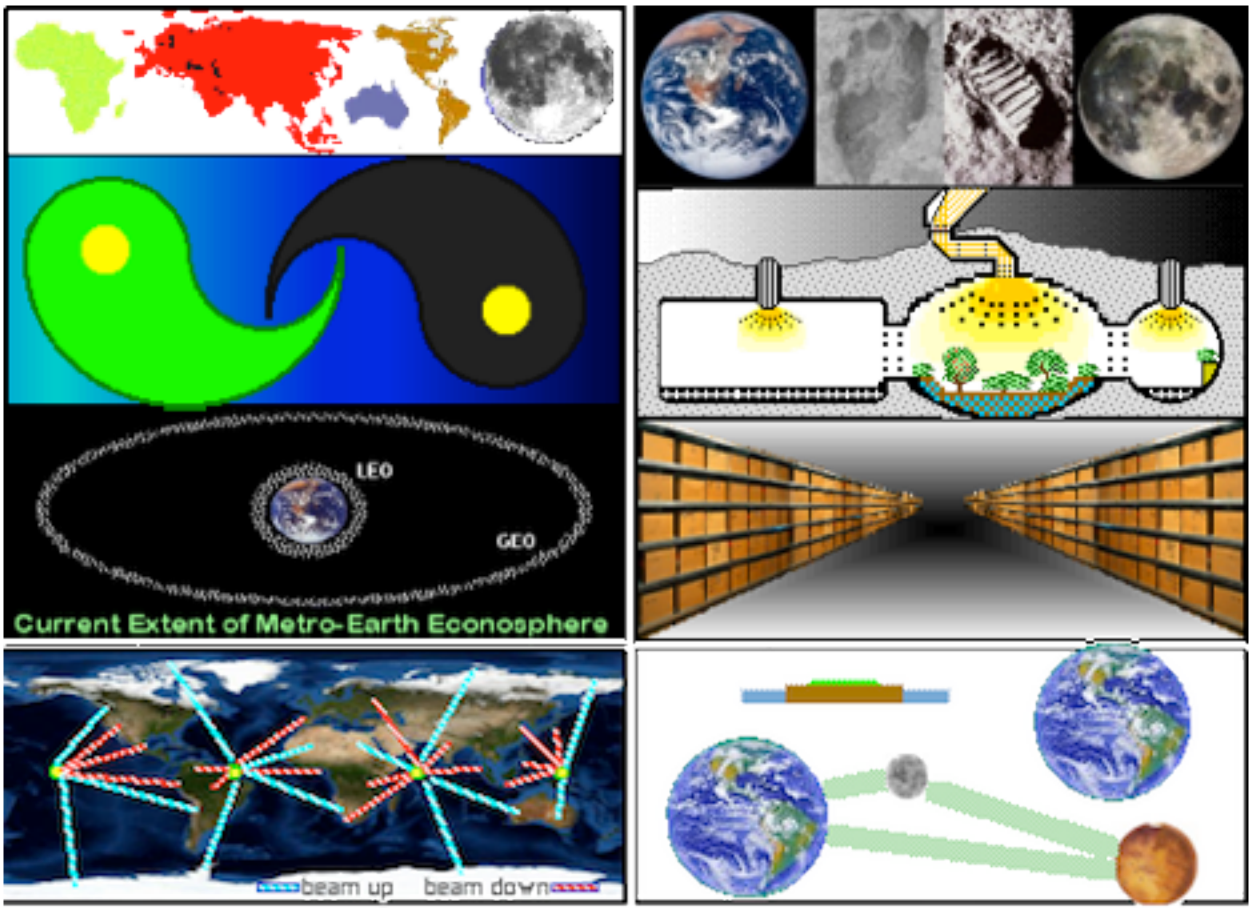
MMM Classic Themes — The Moon: What's in it for Earth?



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MMM # 16

Glass-Glass Composites & “Spin-up”

By Peter Kokh

Glass-glass-composites, more exactly glass-fiber/glass-matrix composites, or simply GGC, are a promising new horizon for construction and manufacture. This new bird in the flock of materials available to man is still inside the eggshell but pecking away at it. What we know of GGC's promise we owe to Dr. Brandt Goldsworthy of Goldsworthy Labs in San Francisco, who at the request of Space Studies Institute in Princeton (SSI) made laboratory-sized samples and investigated their properties (his report is available for 3$ from Space Studies Institute, PO Box 82, Princeton NJ 08540). His work gives reason to believe that GGC building materials will be as strong as steel or stronger, and considerably less costly in energy terms to manufacture. [Note; the above contact information is no longer valid.]

The occasion for this bit of incubation of a theoretical hunch lies in careful analysis by SSI of the possibilities of producing serviceable metal alloys from the common ingredients in lunar soil. While the Moon is rich in iron -- some of it free uncombined fines -- and other important metallic elements such as aluminum, titanium, magnesium, and manganese, these are just starting points; to make alloys with good working properties, other ingredients in lesser amounts must be added. It turns out that our customary and familiar stable of alloys used on

Earth often require recipe ingredients that are not easily or economically isolated from the soil. Furthermore, alloy production takes a great deal of energy and therefore represents a technology direction for a very advanced lunar civilization, and not one for an early base trying to justify its existence with useful exports to LEO or elsewhere. Alloys will come on line someday; it will take young metallurgists without defeatist attitudes ready to scrap Earth-customary alloy formulations and experiment from scratch with avail-able elements until they have a lunar-appropriate repertoire which will serve well. But that is another story. Here we want to explore the tremendous potential of GGCs.

A "Spin-Up" Enterprise Plan

But how can we explore the potential of a laboratory curiosity? We can't. Are we to wait until we get to the Moon and then fiddle around, hoping that we come up with something before the base has its next budget review? You would think so from the present dearth of activity.

Why not haul GGC out of the lab and put it through its paces in the real world? Sure that takes money, but with a little imagination it is easy to see that GGC could become a profitable industry, here and now, on good old Cradle Earth. And if so, our newly acquired expertise and experience will be ready to go whenever the powers that be establish a long-term human foothold on Luna.

What is the realistic market potential that would justify the effort and expense of getting off our bottoms and pre-developing this promising technology now? If we are talking about something only useful for Industrial construction material, then the threshold for successful market penetration is high. Our GGC products must come on-line either cheaper than every competing material or have such superior properties as compared to existing alternatives as to force potential customers to take the gamble. But to limit ourselves, especially at the outset, to such a line of products is not only accepting unnecessary barriers to success, it evidences a great lack of imagination.

Does GGC have a potential for consumer products? This is an important question, for with such products cost can be secondary to other considerations such as visual appeal due to inherent special design and style possibilities, etc. The consumer market could be a much easier nut to crack, and once established and experienced there, our infant industry would be better poised for market entry in the industrial-commercial world.

Before we speculate further, we must take a look at this intriguing new material and put it through the paces to see what we can and can't do with it. Without that, we are building castles in the air.

We have a logical plan of attack for these experiments thanks to the analogy of GGC to a long familiar family of materials with which we have abundant experience: fiberglass reinforced plastic resin composites, the stuff of which we make boat hulls, shower stalls, pick-up toppers, whirlpool spas, corrugated porch roofing, and a host of other handy products. Fiber reinforced plastics or FRPs offer the game GGC entrepreneur a handy agenda for exploring the talents of the new material.

First our enterprising hero will want to see what fiberglass-like fabrication methods GGC is amenable to mimicking. Can (or should) the still hot and workable glass matrix with glass fibers already embedded be draped over a mold to take its form, or be compression molded in a die and press? Can (or should) the glass fiber be set in the mold and then impregnated with the molten glass matrix? (The magic of GGC lies in using two glass formulations: one with a higher melting point from which to make glass fibers, and one with a much lower melting point to serve as the matrix in which the reinforcing fibers are embedded.) Can (or should) the glass fibers be first impregnated with a cold frit of the powdered glass that will form the matrix upon heating in the mold to its fusing point? Once the entrepreneur has learned which fabrication methods work best or can be adapted to the idiosyncrasies of GGC in various test formulations, he is ready for the next round of experimentation.

Fabricating a "piece" of GGC of a certain useful size and shape is only the first victory. We must learn how to machine it: can the material be sawed, drilled, routed, tapped, deburred, etc.? We need to know this before we can design assembly methods. If adhesives are to be used, what works best? Thermal expansion properties of GGC formulation will be important, as well. Once our entrepreneur has done all his hands-on homework, knows what he can do with this new stuff, and has outfitted his starter plant with the appropriate machinery, tooling, and other appropriate equipment, it's time to sit down with his market-knowledgeable partner and decide on product lines.

But let's back up a moment. We said we were going for the consumer market as the ideal place to get our feet wet, and for this market one thing is paramount: visual appeal. So we go back to the lab and start playing around with our formulations. Glass of course is easily colored. Coloring the matrix glass will not provide us with a distinctive product. But colored glass fibers in a transparent glass matrix suggest tantalizing possibilities. The fibers could lie in random directions, be cross-hatched or woven, swirled, or combed to give an apparent grain. We will want to see which of these suggestions are most practical, which have the most stunning and distinguished consumer eye-appeal, etc., all without compromising the strength of our material. As to the colors: black, green, brown, blue, cranberry, and amber would give us an ample starter palette. But before buying up binfulls of the needed ingredients we could do some inexpensive footwork, using abundant and inexpensive green and brown bottle glass for our fibers to give us a first feel for likely results of this avenue of product enhancement. Our homework done, we're ready to burst onto the world scene.

Our recycled long-empty plant (the rent is cheap and a lease wasn't necessary) has been humming for a while now. Production hasn't begun because the designers are still working on the molds and dies for the introductory product line. Buyers and outlets are being lined up. At last Lunar Dawn Furniture Company is ready to greet the unsuspecting world. At first we produce only (stunning of course) case goods: coffee and end tables, etageres and book cases and bedroom sets, etc. Then we introduce a line of tubular patio furniture that makes the PVC kind look gauche. Next we branch into an upholstered line with beautiful external frames. Office furniture, striking unbreakable fluted glass lamp shades, stair and balcony railings, and unique entry doors are our next targets. Our prices are somewhat high at first, at least with the initial lines, but we were the rage at the fall furniture show in North Carolina and the spring Home Shows in every town. Lunar Dawn takes it's place beside Early American, Mediterranean, Danish Modern, and Eighteenth Century English.

We introduce less expensive but still appealing lines and franchise our operations, targeting especially the less developed nations that need to curtail their forest-razing and which have an abundance of the raw materials needed for glass making. But we also begin to diversify into the commercial and industrial markets. We've learned to make beams and panels and now offer a whole line of architectural systems for competition with steel and aluminum pole buildings, etc. One of our branches is now marketing GGC conduit and pipe at competitive prices. Another is offering a full range of clear non-laminated safety glass for buildings and vehicles.

Meanwhile, we are not resting on our laurels in the consumer world. Casings for small appliances, cookware, ovenware, and table ware; handles, wash basins, and countertops; boat hulls for boulder-studded white water use; all are now available in GGC. A big hit with the fans is our indestructible flagship in the sports world, our GGC bodied Demo Derby Dragon. The same car has won its first dozen events and looks none the worse for it.

Of course, we've long since abandoned the cumbersome GGC or Glass-Glass-Composite tags. The public got what it needs, a simple one syllable pigeonhole. We're known and recognized everywhere as "**GLAX**", a word suggesting glass with a difference: strength. And visually, the "ss"-replacing-"x" even suggests the dual composition involved. Glax is a generic term like steel or wool and even has its own generic logo, a symbol for public recognition and promotion.

You'll see in the logo symbol an allusion the Moon. For the ulterior motive inspiring the people behind the successful Glax entry into Earth markets was the need to predevelop a technology suited for early lunar bases and settlements. Glax will provide a relatively inexpensive, uncomplicated industry for the settlers both to furnish badly needed exports, and just as important, a whole range of domestic products that will help hold the line on imports. As such, Glax is an essential keystone in the plan to achieve economic viability and autonomy for the projected City.

There is a lot of enthusiasm on Earth now, not just for a lunar scientific outpost à la Antarctica, but for a genuine settlement. This change of attitude did not happen by accident, and the story of Glax on Earth played a major role in this turn of events. Glax, since the first door-opening day of Lunar Dawn Furniture Company, was aggressively marketed as an anticipatory lunar technology. The public began to get the idea that moon dust might be good for something and that the idea of a self-supporting settlement relying largely on its own resources was not a flake notion, but rather something reasonable, even to be expected! Lunar Dawn helped the process along when after moving into its brand new plant in suburban Milwaukee, it built a simulated lunar home next door, soil-sheltered and all, with solar access, periscopic picture windows, ceramic, glass, and metal interior surfaces, and of course furnished with its own Glax furniture lines. The habitat was accessed by "pressurized walkway" from the meeting hall-display room-library-computer network room and gift shop built alongside and used free of charge by Milwaukee Lunar Reclamation Society.

How did this all happen? Notice the fine print on Lunar Dawn ads and billboards (also used in connection with other Glax product companies): it reads "An Ulterior Ventures Company". Ulterior Ventures isn't some big conglomerate but a unique venture fund which the National Space Society helped to organize to give entrepreneurs willing to predevelop anticipated lunar technologies for Earth markets, a little help to get started. Successful members of the Ulterior Ventures family pay a royalty which helps build the fund for even more ambitious exploits. In future articles we hope to tell you about other successful -- if not so well known -- members of the Ulterior Ventures family.

Future Fact or Science Fiction?

Fiction? Yes. Unrestrained flight of fancy? No! This is the sort of thing that could happen with NSS encouragement, if the society can be persuaded to show the same enthusiasm for direct action as it always has for indirect agitation "to make it happen". Having to start from scratch to build the infrastructure to incubate and support such "ulterior ventures" would mean an unwelcome set-back in time, effort, and personal energies.

The brand new infant industry sketched above does not require expertise in preexisting sophisticated technologies to get started. Almost any of use could get in on the ground floor of such an endeavor in one or more capacities. Any takers? -- Peter Kokh May 1988

MMM # 22

1st EXPORT$

A 1988 SSI Brainstorming Workshop

Reported by Peter Kokh

The Team

In MMM #20 "STATION MATE" we reported and commented on Space Studies Institute’s 1988 brainstorming Lunar Systems Workshop session that addressed commercial and entrepreneurial opportunities in Low Earth Orbit (LEO). In this article we'd like to report on the work of another team at this same workshop, this one addressing Lunar Surface Operations.

The team budded a “Quick Payback” Subgroup consisting of Edward Bock of General Dynamics, Gregg Maryniak and Rick Tumlinson of Space Studies Institute, Robert Temple of Pacific Institute, and Brian Tillotson of Space Resources Associates of Seattle. The group's goal was the same: 'to create one or more scenarios or business plans for the productive use of lunar materials', guided by the “philosophy that independent, profit-making space businesses could provide a robust, non-reversible course into space.”

Goal: Identify Profitable Opportunities from robotic missions to the Moon

In particular, the Quick Payback Subgroup looked for openings for economic gain from early precursor missions prior to actual human return to the Moon and establishment of a Lunar Base. In this way, the path back to the Moon could be 'terraced' with economically justifiable steps that would both guarantee and hasten the ultimate goal of using lunar resources to build a space-based civilization.

The first product or export to be gained from precursor missions would be salable information. A three tier scenario was outlined in which the information product from one mission would help boot-strap the next mission.

Information from Teleoperated Rovers

The first mission would entail a one-way lunar lander with a ten [metric] tonne payload to include six small teleoperated rovers weighing four tonnes together, a two tonne pilot liquid oxygen production plant, three tonnes of avionics, and one tonne consisting of TV cameras and transmitter, a robot arm and hand, and a demonstration electrostatic or electromagnetic iron beneficiator.

The purpose of the teleoperated rovers is, of course, soil sampling and site investigation. But before they are deployed to their first target assignments, 'income could be earned by a teleoperated rover race' between individuals on Earth from companies that will have built them 'for free for the promotion value', or between teleoperators who will have bid on the rights to participate in this "race of the millennium".

This form of prior sale will cut the costs of such a mission to $200 million about half of which would go to Energia-class heavy lift vehicle transportation. The camera equipped rovers could earn additional revenues by providing moving pans of lunar landscapes for movie productions and as backdrops for commercials, with a capacity for 'live' footage.

An Ambitious Soil Return Mission
Plus Liquid Oxygen Production
Plus production of glass & iron trinkets

The next mission would be more ambitious and include a 1.5 tonne sample return of lunar material [the sum total of Moon Rocks returned by the six Apollo missions was 841 lbs or .38 metric tonnes] and also a 2nd generation liquid oxygen production plant with the capacity to process small amounts of lunar glass and iron [included in the lunar soil run through the plant] “into high value products for sale on Earth, such as lunar iron ‘coins’ and lunar glass ‘jewelry’.

The value of such products on a back-home market is highly speculative and depends almost entirely on demand. The group optimistically hopes for a sustainable demand for such coins and jewelry in the $300-500 per carat range. [By way of comparison, this is over 100 times higher than the going rates for gold or platinum. But a check with a local jeweler gives the current (2/'89) price range for diamonds as $1800 to $100,000 per carat depending on quality.]

This second mission would likewise deliver 10 tonnes to the Moon, but this time, half of that would consist of the sample return rocket. If the target $500/carat yield is realized, the mission would earn a tidy $750 million against its cost of $200 M.

The third mission would bring up a 3rd generation LOX plant, return fuel and an aerobrake equipped rocket. The mission's purpose would be to demonstrate the profitable return to LEO of a sizable 8 tonne payload consisting of LOX (liquid oxygen rocket fuel) and more made-on-Luna trinkets, with up to $1.4 billion profit at a now slumping $200/carat.

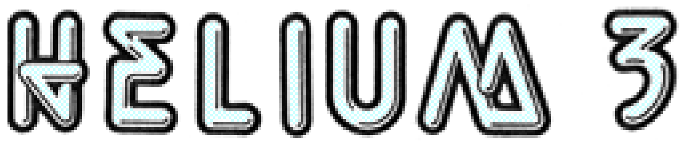
While the payback figures hoped for remain highly speculative, the study does give much encouragement to the expectation that Lunar EXPORT$ can commence prior to human return.

**[Cf. FIRST STEPS TO LUNAR MANUFACTURING: RESULTS OF THE 1988 SPACE STUDIES INSTITUTE LUNAR SYSTEMS WORKSHOP by Gregg E. Maryniak, Executive Vice-President of Space Studies Institute. The complete report is available for $10 from SSI, P.O. Box 82, Princeton, NJ 08542.]

Note: the above contact information is no longer valid **MMM**

MMM # 23

Tailings



HELIUM-3

By Eric Ryden, Chicago Space Frontier L5

The January 1989 issue of Fusion Technology contains a report of the 1988 NASA Lunar Helium-3/Fusion Power Workshop. The meeting addressed the potential of mining helium-3 (3He) from lunar regolith for use on Earth in fusion energy, assuming practical 3He use around 2015. Researchers at the University of Wisconsin-Madison had proposed lunar 3He mining[1], based on previous analysis of lunar soil samples that showed that the Moon serves as a collector of helium deposited by solar winds. Natural 3He is scarce on Earth,The workshop assessed fusion energy methods and approaches for lunar surveying, mining, processing, storage, transportation, and facilities required for recovery.

Fusion involves the combination of light element atoms into heavier atoms to produce energy. [Ed. Fusion creation of atoms lighter than iron producing energy, of elements heavier than iron consuming energy.] In comparing deuterium-tritium fusion which uses two isotopes of hydrogen, with deuterium-3He fusion, the latter was considered to produce less radioactive wastes and higher electricity conversion efficiency, but would be more difficult to ignite and contain.

Analysis of lunar regolith showed that higher titanium dioxide (TiO_2) levels correspond to higher 3He levels, a relationship which could not be explained. Distribution of TiO_2 might be made by remote sensing to infer 3He distribution, since 3He cannot be directly detected. [Ed. Higher titanium concentrations are found principally in some mare basalts. We may also want to map high-titanium basalt distribution in the maria to locate the best concentrations of ilmenite, an iron-titanium ore whose processing would produce liquid oxygen.]

Most 3He is concentrated in regolith [fines] smaller than 50 micrometers, thus screening and sorting collected material for this portion is desired. Following processing, separated helium would require isotope distillation to obtain 3He from the more prevalent 4He. Isotope distillation could be performed on the Moon or after transport to Earth [Ed. involving a severe weight penalty for the included unsalable 4He].

Lunar oxygen production from ilmenite ($FeTiO_3$) after 2000 could demonstrate lunar mining and processing, as well as genera-ting metals and small amounts of 3He as byproducts.

However, this process is not efficient for 3He production because most helium would be lost in the concentration of FeTiO3 from regolith. Alternatively, heating regolith for 3He production also creates volatiles such as water, which could be utilized for other lunar activities. Thus the existence of either a lunar base or a 3He production facility could affect the planning and development of the other.

Further details of the workshop are contained in NASA Conference Publication 10018.

1 Wittenberg, L.J., Santarius, J.F., and Kulcinski, G.L, "Lunar Source of 3He for Commercial Fusion Power. Fusion Technology 10:167-178, 1968.

ER

MMM # 31

"GREEN EARTH, CLEAN MOON"
A PHILOSOPHY TO BREAK OUT OF CRADLES BY

By Peter Kokh kokhmmm@aol.com

It is hardly possibly to turn on a TV or radio these days with out hearing about some needless environmental disaster or another instance of criminal toxic waste dumping. As if the devil-take-the-hindmost side of American business were not enough, we are all becoming painfully aware of our own unintentional guilt in passing on to our children an Earth less green, atmosphere less fresh, water less pure, forests less vast, and wildlife less abundant than those we had inherited.

It is understandable that many of us are beginning to think of humanity as a cancer upon the good Earth. Greenpeace, an extremely active international environmental group, is lobbying to set aside all Antarctica as a World Natural Preserve, banning even scientific bases as an infringement. Give Greenpeace a time machine and its warriors would go back ten thousand years to prevent the first Siberian Indians-to-be from crossing the Bering Strait (or isthmus back then) so the Americas could remain unspoiled wilderness. Perhaps if they could go back further, they would have stood guard in the Sinai to limit mankind's ravages to Africa.

Both the trouble with this attitude, and the very real trouble that humankind poses for the environment, are grounded in the same 2000-year-old unquestioned acceptance of the premise that mankind and nature are opposed. Rather we are part of nature, a new part, a part that appears as Earth-life enters puberty. Indeed, Earth-life as a whole, or Gaia as it is now coming to be called, cannot reproduce itself, scatter its seed to worlds beyond its cocoon of space, without humanity. To reproduce, Gaia must undergo the anxious pubescent changes and adolescent tribulations that being-with-humanity brings with it. By the same token, it is not humanity that will go to "the Moon, Mars & beyond", it is Earth-life-including-humanity.

Quite frequently one hears the objection, why should we go back to the Moon? "Isn't polluting one world enough?" The legitimate disgust the speaker feels for what is going on here on Earth is being transferred to the speaker's expectation of what must supposedly follow in space.

"Mankind will not change. As our reputed ancestors cannot be housebroken,
it seems that we cannot be planet-broken. We are fated to go on fouling out nest forever."

It is impossible to argue with pessimism, because, like optimism, it is grounded in temperament rather than reason. To those who wish to take the meliorist alternative - acceptance of the given as bad as it is with the determination to take it upwards from here - there is not only hope that we will change and are changing our act here on Earth - with painful and halting steps, yes - but it is also clear that the "opportunity" to foul our own nest will not follow us beyond our home planet!

Whether our stripes change or not, there are no forests on the Moon to cut, no air to poison, no groundwater or streams to pollute, no wildlife to drive to extinction. We are a danger to established biospheres, yes. But there is no biosphere on the Moon, nor Mars, nor anywhere else in the Solar System within our reach.

To live on the Moon, we must on the contrary bring mini-biospheres of Earth-life with us. But whereas on Earth we can do our mischief and not worry about the consequences till much later, the tiny islands of life we bring to the Moon and Mars will be far less forgiving. We sin against them, we pay the price pronto.

It becomes obvious that Lunar and Martian pioneers will have had to change their act under sentence of death. Not only will they have to live clean, work clean, and play clean, but they will, especially on the Moon, have to recycle totally (read 100%) all the things we are used to throwing away on Earth. It isn't that they will lack places to throw things. Rather, the hydrogen, carbon, and nitrogen that largely make up wood, paper, plastics, and synthetics are not easy to come by on the Moon and may have to be imported at very high expense. Everything thrown away must be subtracted from the standard of living. Indeed, pioneers will use precious little of such materials to begin with.

In learning to thrive on the Moon, hopefully before we go, we will learn many lessons and some valuable knowhow that will help us improve things here on Earth. While the motivation to clean up our act on Earth is weak but growing, on the space frontier, it will be do-or-die.

What about mining? Won't we scar the 'magnificent desolation' of the Lunar landscape? In truth, all the resources on the Moon are already lying loose in the regolith, the pre-pulverized and ready-to-scoop-up-and-process upper few yards of its surface. There is no need to either strip mine or deep mine or otherwise change the appearance of the surface. The eons-long processes that worked on Earth to concentrate ores in isolated veins and strata did not operate on the Moon. Yes, we can be sloppy, littering whatever does happen to be cheap. Only public care can prevent that.

To sum up,

We must reject the offered dilemma of a Virgin World versus a Raped World. MMM

MMM # 32

IMPORT / EXPORT EQUATION

IMPORT/EXPORT EQUATION

By Peter Kokh

To survive, a settlement must earn more in exports than it pays for imports

A. Settlement Import Categories And Strategies to Cut and/or Avoid Them

1. CAPITOL EQUIPMENT: “MUS/cle” co-manufacture is easily the most promising approach. A minimal sintered iron and glass composite manufacturing capacity must be imported first. Thereafter, complex lightweight electronics-rich ("cle") "works packages" from Earth are mated to Massive Unitary Simple ("MUS") parts made on the Moon of Lunar materials and assembled on the site to make additional equipment for Energy Generation, Mining & Processing, Manufacturing, Construction, Fabrication & Repair, and for Food Production. [cf.: "M.U.S./C.L.E." in MMM #18 September '88 pp. 10-11 above]

2-SETTLERS: "Bantamweights" will do. For Prinzton will be run with brains rather than brawn.

Weight savings on settlers can be applied elsewhere.

3-FARM PLANTS AND ANIMALS: Seeds only, and worms and bee colonies; Seeds packed in hot pure N2 to kill hitchhiking pests; Unpatented non-hybrid cultivars only; and pregnant female animals only.

4-VOLATILES: Hydrogen, Carbon, Nitrogen: The import burden can be softened by some careful measures faithfully pursued:

(a) Harvesting, by heating, of the significant quantities of H, C, N, and other gases adsorbed to the fine regolith particles, thanks to eons of bombardment by the Solar Wind, during all those construction processes involving soil moving;

(b) Out-sourcing to gravity wells more shallow than Earth's e.g. Phobos and Deimos, Earth-approaching asteroids and comets;

(c) Conservation of volatile-rich organic materials by religiously thorough recycling efforts. In support of this goal Prinzton will need "kosher" (organics not bonded to inorganics) knock-down-friendly ("KD") assembly methods; systematically thorough and foolproof sorting clues and handy routing managements; and above all the help of ingrained second-nature good habits and expected chore assignments.

(d) 'Pre-codesigning' of all single-use containers for volume-matched secondary more durable uses. (An example already attempted was the elusive "World Bottle" design i.e. a bottle that could be reused as a brick; Effort not yet successful.)

(e) Buttoning up pressurized areas for Nitrogen conservation by use of novel airlock systems: Matchlock “intergates” to allow suitless shirtsleeve transfer between vehicles and habitat areas; Liquid airlocks for some freight categories such as goods manufactured inside for use in vacuum and vice versa; and turtle-back spacesuits that back into special mated airlocks for direct entry from suit to habitat and vice verse.

5-RARE METALS: An elegant way to painlessly "co-import" rare metals, and even some synthetics is by making all needed shipping containers end packaging out of such materials i.e. the easily forgotten category of "Tare". [Gross - Net = Tare] Making this standard practice could provide a tidy "cheap" endowment of badly needed materials hard to process from the Lunar soil such as copper, brass, other precious metals, other needed alloying ingredients, and even some volatiles in the form of lightly polymerized synthetics. Crates, Boxes, Barrels, Tanks, Cans, Bottles, and packing stuffing and dividers could all be made of such strategic materials.

6-HABITATS: To make the Prinzton construction camp, an original minimum number of tight-packed space station module type sardine cans can be followed by locally manufactured and constructed Big Dumb Volume Structures in which are placed "Works Core Modules" made on Earth. Such cores would contain Kitchen/Bath facility, electrical service, communications-entertainment center, air conditioning-heating-leaning unit, etcetera. The total core package would be lighter (no massive hull) and cheaper to upport from Earth and the host habitat would be much more spacious and cabin-fever resistant. Such Works Core Modules, but with an ever greater Made-on-Luna "MUS/cle" content, also serves in Prinzton's Village Homes.

7-NON SELF-MANUFACTURED GOODS: For those needed and desired items Prinztonians need but are not yet capable of providing for themselves, the "MUS/cle" formula is again part of the answer. But substituting metal, glass, Glax* [composites], and ceramics wherever possible for wood and plastics, and doing without wherever this is impractical must be Plan A. Mail order catalogs from Earth will be taboo and instead items from the hands of local artists and craftsmen will be treasured. A paperless all-electronic society will be a top priority goal. [cf: "Paper Chase," MMM # 4 April 1987, republished in MMMC #1.]

B-Strategies to Lower Import Costs and/or Increase Import Quantities

1-ALTERNATE SOURCES: Prinzton will need to import considerable quantities of hydrogen, carbon and nitrogen, most easily handled in the form of methane CH4 and ammonia NH3. Discounting the amortizable capital costs of emplacing the needed equipment, these volatiles can be shipped at a fraction of the total fuel cost, from Phobos or Deimos, moons of Mars, at regular 26 month intervals. Such shallower gravity well sources also include occasional catch-as-catch-can Earth-approach-ing asteroids, comets, and wildcat-worthy inactive comet-hulks. The Moon's deficiency is the Solar System's gain. For settlers will have a do-or-die urgency in pioneering such markets.

2-LOWERING COST-OFF-EARTH will be above all a matter of developing (at last!) more economical surface-to-orbit launch systems. But our crafty settlers will also attempt to lower prices FOB Earth by buying goods on favorable terms Solar Power Satellite customer nations.

3-LOWERING COST-ONTO-MOON. Unlike both Earth and Mars, the Moon has no handy atmosphere to allow aerobrake assistance. But there are other more inventive alternatives to full retrobraking. These may include skid-landing on prepared regolith smoothways. [Lunar Bases and Space Activities of the 21st Century, W.W. Mendell Ed.r, Lunar & Planetary Institute, Houston 1985 pp. 848-50 "The Lunar Slide Lander" by Kraft A. Ehricke] and the "Edportation" scheme of inventor Ed Marwick. Passengers may not line up for such wild rides, but drone "sliders" could bring in needed bulk materials and other hardy cargoes.

C-LUNAR EXPORT CATEGORIES

1-BULK MATERIALS: Liquid Oxygen; Regolith for shielding; Enriched ores for space processing.

2-OXYGEN CONTAINING PRODUCTS such as Water and Foodstuffs cheaper than from Earth even if they contain terrestrial Hydrogen and Carbon.

3-BUILDING MATERIALS AND COMPONENTS: Iron and Steel; Aluminum, Titanium, Magnesium alloy; Glass and Glass-Glass Composites; Ceramics & Concrete.

4-ITEMS MANUFACTURED ON THE MOON to cut imports are also marketable to LEO, GEO, L5, Mars Ph/D (Phobos, Deimos): Furniture and furnishings; Tanks, Holds, Appliance Cases, other items.

D-EXPORT DESTINATIONS

Low Earth orbit Space Stations and other manned facilities, Space Colony Oases at L4/L5 or in other orbits, and Mars-bound expeditions are all Markets for Lunar Lox, Food, Water, building materials products, and sundry finished goods all Lunar or MUS/cle assembly). Geosynchronous orbit is a destination for large multi-satellite capacity platforms and Solar Power Satellites.

E-STRATEGIES TO INCREASE EXPORTS

1-LOWERING EXPORT LAUNCH & DELIVERY COSTS:

Mass Drivers, Bucket, and Pods should be upgraded to launch more profitable value-added goods.. 1st Upgrade: enriched beneficiated ores: Fe, FeO, TiO, Al203, CaO, MgO, SiO; Batch-loads of glass matrix, glass fiber, and cement. Second Upgrade: right-sized ingots: Fe, Al, Ti, Mg. 3rd Upgrade: shock-proofed pods of small manufactured parts. In addition, goods bound for Earth's surface could be shipped in no-transfer self-contained Earth-aerobrake-and-Land "dynasoar" capsules.

2-INCREASING MARKET DEMAND: Liquid Oxygen: Would-be-Prinztonians should push development of "Stage Plus" Earth Deep-Space Launchers designed for on-orbit LOX refueling. Food deliveries to LEO stations and other space locales, will depend on selection, delivery, marketing.

Building Materials: Lunar-owned Space Architecture and Space Construction Firms will channel a greater share of space construction profits back to the Settlement. Promotion of 1/6th G lunar Gravity as a Standard for rotating space structures will mean quicker, more frequent sales because the rotation rate linked minimum size and mass of such oases will be a magnitude smaller, a more attainable threshold.

Prinzton made Consumer Goods can be promoted along with Lunar-type material culture in general as the appropriate norm for near Earth facilities in the era of still expensive volatiles. Such goods involve material substitutions and a high profile for Art/Craft made wares.

Promotion of the Moon as the "Hub" of the ETM (extraterrestrial materials) economy will be an essential settler policy. Their do-or-die motivation and proven knowhow will drive Lunar-initiated market development of Mars and its moons, and of the Asteroids. Key here may be the development of Minimal Mobile Biospheres. The larger deep-space long-cruising vessels have to be to hold self-contained mini-biospheres, the greater the obstacle to opening the asteroids.

3-MARKET TARGETING: Logical Earth Trading Partners for Prinzton are those nations which are at once • Energy Importing Countries (Solar Power Satellite sales, Helium-3 sales) and • Sources of elements not economically Lunar-sourceable yet strategic to Prinzton development. Many of these countries are in the “Urban Tropics.”

4-MAXIMIZING TOURIST INCOME. The lure to well-heeled sightseers can be intensified in several ways.

A "**Seven Wonders**" **list**, carefully drawn up and publicized, and a variety of enticing itineraries will encourage repeat trips or at least longer stays.

Special ways to taste the settler way of life can be offered to visitors.

- Stays in lunar homes
- working tours
- Art & Craft classes
- special tours e.g. of factories and recycling systems, and
- the opportunity to actually participate in unique Lunan sports.

Customs regulations can entice tourists to trade all their Earth garb (for Lunar Stage/Theater Use) in exchange for souvenir Made-on-Luna apparel.

Shopping Spree Tours for unique arts, craft, and clothing pieces at the Settlements cottage industry flea markets should be marketed.

5-TELEVISION & FILM MEDIA SALES:

Advertising Revenues could be appreciable enough to wholly finance: • Development of Unique Lunan Spectator Sports, which in turn could be televised to Earth audiences hungry for something new and exotic.

• Construction of any facilities such sports may require

• The same goes for the "ethereal" Prinzton Ballet Company, probably awaiting the coming of age of the first native-born generation.

• Documentaries about Prinzton and Lunar activities at large will vie with space adventure films for the use of the Out Of This World film studio in Prinzton.

6-EXPORTING KNOW-HOW: Technology transfer is a potential money-maker for Prinzton. Hopefully much of the technology needed to make Prinzton a thriving reality will have been predeveloped for profitable terrestrial applications and thus served to keep Prinzton's up front costs far lower than they otherwise could be. But enterprising young Prinztonians will develop new products and processes salable Greenside. <**MMM**>

DIVERSIFICATION
$$$UB$$$IDIE$$$

By Peter Kokh

+ **EXPORTS**	We have outlined a very ambitious
- **IMPORTS**	picture of what a mature
= **BOTTOM LINE**	Prinzton economy might look like.

But what is the logical order in which such a well-rounded economy might be best achieved? Diversification will in part depend on a number of things that we cannot accurately forecast at his time:

- **Size of the LEO market** for LOX, building materials, other manufactured goods

- **Progress in opening up space markets elsewhere**, e.g. Phobos/Deimos etc.

Different scenarios can be plotted assuming various values for these unknowns. But we can list some pertinent questions and their answers will greatly affect our strategy and game plan.

For each industry proposed for Prinzton, we will want to know the following:

(1) What is the industry's capacity to **generate export tonnage?**
( ) Major – ( ) Medium – ( ) Minor

(2) What is the industry's capacity to **defray import tonnage?**
( ) Major – ( ) Medium – ( ) Minor

(3) What is the **export value-added** per tonne?
( ) Major – ( ) Medium – ( ) Minor

(4) To what degree is the industry **labor intensive**?
( ) Major – ( ) Medium – ( ) Minor

(5) To what degree is the industry **energy-intensive**?
( ) Major – ( ) Medium – ( ) Minor

(6) What is the industry's **pressurized acreage need**?
( ) Major – ( ) Medium – ( ) Minor

(7) How well can the industry's operations be separated into **successive** diurnal (dayspan) **energy-intensive** vs. nocturnal (nightspan) **labor-intensive portions**?
( ) Major – ( ) Medium – ( ) Minor

(8) How much **heat** is **needed** for operation?
( ) Low – ( ) Medium – ( ) High

(9) How much **heat** is **generated** by operation?
( ) Low – ( ) Medium – ( ) High

(10) What is the industry's **need for vacuum?**
( ) Major – ( ) Medium – ( ) Minor

(11) What percentage of **chemical reagents** used can be **recycled**?
( ) Major – ( ) Medium – ( ) Minor

(12 a) To what extant can the industry be **set up in modular units** so that production capacity can be easily increased as needed?
( ) Major – ( ) Medium – ( ) Minor

(12 b) How high is the import tonnage of each module in terms of economic gains?
( ) Major – ( ) Medium – ( ) Minor

(12 c) To what extent can **MUS/cle*** co-manufacturing savings be applied to additional modules needed? [* see the article from MMM #18 above pp. 10-11]
( ) Major – ( ) Medium – ( ) Minor

(13) What **prior industrial material by-products** are presupposed?
( ) Major – ( ) Medium – ( ) Minor

(14) What **prior processing capacities** are presupposed?
( ) Major – ( ) Medium – ( ) Minor

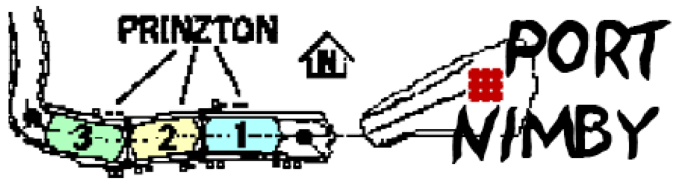
(15) What subsequent industries are e**nabled by new byproducts** generated?
( ) Many – ( ) Few – ( ) None

(16) What subsequent industries are enabled by processing capacities offered?
( ) Many – ( ) Few – ( ) None

(17) How "**ready-to-go**" is the technology for operation **in Lunar Conditions**?
( ) Little – ( ) Partly – ( ) Go!

Once we've done our homework on these and similarly relevant questions, **we will be ready to begin a serious discussion** of long-term **Lunar Industrialization Plans**

"Not In My Back Yard" - "N.I.M.B.Y."



IMPORT/EXPORT SLEEPER Gross Imports that Could Count as Net Exports

Peter Kokh and David A.Dunlop

IMPORTING FOR DIRECT PROFITS

This may seem like a Cinderella idea. Prinzton already works toward over-all net profits by putting major emphasis on importing capital equipment to help both lessen the need of further imports and increase exports by enabling ever more local processing and manufacturing MUS/cle (see the article from MMM #18 in MMMC2, pp. 34-35) and co-importation by clever choice of tare materials. (see previous article "Diversification/Subsidies")

Every Trade Czar's fairy tale dream, however, is to be paid for the imports one's people need, rather than paying for them. Simply put, this means agreeing to take something unwanted-with-desperation off the hands (and minds) of some other bailiwick. Highly Toxic Chemical Wastes, Virulent Biological Wastes, Radioactive Wastes - might all fit this description.

"**Not In My Back Yard**" - "**N.I.M.B.Y.**" is the classic universal reaction to these leprous by-products of today's advanced technology. In recent years, the unwelcome reality that every where on Earth is someone's back yard, is slowly sinking into the public consciousness. Governments continue to search for cost-effective-yet-safe ways to store or neutralize such techno-feces but it seems to be a hopelessly intractable problem. Promising solutions emerge only to be found fraught with fatal flaws.

Perhaps we need only be patient and elegantly "safe-yet-cheap" solutions will present themselves. But perhaps not. Meanwhile, problem wastes will keep on accumulating at an alarming rate so long as we do not wish to face the fact that those desirable materials that involve such byproducts may not be worth the ultimate cost.

Space to the Rescue? Ahah! You say. "Space to the rescue!" Several space-involving solutions to this runaway problem have been proposed.

(a) Let's move the offensive Chemical Processing and Biological Engineering Plants to LEO, low Earth orbit, where wastes can be dumped harmlessly in space. Alas, we are now learning, LEO is a very temporary place and everything parked there will eventually find a way back into the atmosphere. We must go well out, beyond the Van Alien Belts, to a realm ruled by the Solar Wind rather than by tenuous tentacles of our atmosphere. GEO, the Earth-synchronous orbit that is home to most communications and weather satellites, will do, as will the L4/L5 Earth-Moon libration points, or high-perigee Earth- Moon resonant orbits. The Solar Wind would carry offensive exhausts well beyond the outermost planets. (Heliopause smog?)

(b) "**Dump the stuff into the Sun**" seems the ultimate solution to those blissfully unmindful of common orbital mechanics facts-of-life. Of all space solutions proposed this is surely the most outrageously expensive in "Delta V" i.e. fuel expenditure requirements. First our skull-and-crossbones payload must be accelerated to some 25,000 mph just to reach the shoulder of Earth's gravity well. Then it must shed All of Earth's forward orbital speed, another 66,000 mph worth of velocity change. A short burn, short by any amount, would result in a highly elliptical orbit, bringing our "Flying Dutchman" alternately in towards the Sun and back out to Earth's orbit. In contrast, it would be far cheaper, in terms of fuel cost, to catapult this dreaded stuff in the other direction, out of the Solar System altogether. Another cheaper possibility would be to shoot for the all-engulfing depths of mighty Jupiter, as we hope to do with part of the Galileo probe in December, 1995.

(c) Expel it from the Solar System. An even less expensive option than feeding the Sun, Jupiter, or the interstellar dust and gas clouds, is available to some future Dreaded Wastes Authority. We could rocket our nasty stuff into simple Solar Orbit, tele-open the canisters, and let the Solar Wind provide the Delta V, gently but inexorably blowing the stuff out of the System.

"One person's trash is another person's treasure"

Back to the drawing board

But all of the above suggestions choose to ignore the bit of wisdom that "one person's trash is another person's treasure".

All three of the problem waste categories we are discussing, are problems because of the over-context of Earth's Active Geology and Encompassing Biosphere.

This given geo-context renders inherently dangerous any and all methods of value recovery by incineration, distillation, electrolysis, precipitation, or whatever. Take the stuff out of this context and the entire situation has changed.

Toxicity = toxicity to something

Absent one of the two terms (biosphere) and it becomes totally illegitimate to continue to call the substances in question "toxic". Now, in this changed situation, we can talk possibilities fruitfully!

The next step is to determine where these troublesome wastes might have salvage value. You guessed it! - to settlers on our volatiles-impoverished Moon! To illustrate the potential of this Lunar Solution, we included Port Nimby on the periphery of the Prinzton Settlement Site. [see map hint in title art above.]

However, our settlers could afford to pay to import such tainted volatile-rich (hydrogen, carbon, nitrogen plus extras) shipments only if they were subsidized by desperate terrestrial authorities to the point that they would be markedly cheaper than the alternative Phobos-Moon "pipeline", with the much greater cost and difficulty of clean processing of the NIMBY hot stuff. Of course, if the shipments were free, F.O.B. Port Nimby, that would be ideal. That is unlikely, however, as one could expect custodial authorities on Earth to foot the bill to toss the stuff out of Earth's gravity-well but not the additional cost of soft-landing it on the Moon. Free "F.O.B. L1", on the crest between the Earth's and the Moon's gravity wells, is about all our settlers can realistically expect.

The biosphere discontinuity (the extremely hard vacuum and the total absence of ground water) between Prinzton and Port Nimby is what makes such an option many orders of magnitude safer than the most ideal of storage-on-Earth schemes.

Storage in lava tube sections, which have to date survived intact for nearly four billion years, leaves no rational basis for qualms of informed conscience. This is not case of disrespect for the Moon, anymore than it would be for the Sun. Again, toxics are not disrespectful to the Earth geologically considered, but only biologically considered. That is, they disrespect Gaia (the new name for Earth's biosphere) not Earth itself. In contrast the Moon has no biosphere whatsoever, and the totally encapsulated minibiospheres that we will establish there, can be easily kept rigorously isolated.

What's in it for the Settlement?

Much of the salvage processing of these "profitable imports" could be done robotically and/or by teleoperation from the safety of isolated bunkers.

The prizes to be gained are recovered **water** and **carbon dioxide**, and possibly **organic feedstocks** for production of those synthetics for which the settlers are not able to make inorganic substitutes, or reasonably do without

They might also "mine" the ash for **heavy and precious metals**.

Special "designer" bacteria night be of help in the process, though the sheer variety and probable careless premixing of wastes Earthside would tend to make this impractical as a general approach. It is possible, of course, that we will develop safe methods of detoxifying such wastes on Earth and/or quit producing them in the first place.

The point may never be reached where the lunar solution becomes economically attractive. A lot depends on when and if transport costs come down substantially.

Radioactive Wastes

What about Highly Radioactive Wastes? This is a considerably more stubborn problem. No storage site on the geologically active Earth can be safe for the full length of time needed, excepting possibly the deep-injection of such "hot" wastes into active subduction zones, for example where the Pacific plate is slowly diving under the advancing North and South American continental plates. By the time, if ever, such dumpings reemerged up some volcanic throat after tens or hundreds of millions of years of mixing with molten magma deep below the crust, no problem would remain. If that solution remains an impractical dream, then the intractability of the problem could make the lunar option very attractive.

Mining Radioactive materials for power and water

But how would settlers put such shipments to use? Perhaps they could be densified by distillation into significantly hotter concentrations, useful for generating Nighttime Power. They would be reclassified from "fuel" to "waste" when the power density they support falls below a certain level economically useful for the competitive generating stations on Earth. Yet they might still yield economical power in the quite different lunar economic environment.

Any water in which these hot shipments are stored for shipment, once repurified, would be a very welcome free addition to the settlement reserves. Further, radioactive wastes might also come in very handy for maintaining thermal equilibrium for the settlement. And the temperatures generated might allow continued nighttime operations of some Industries using concentrated solar heat by day such as glass and ceramics production and other "lifeblood" enterprises.

There are a lot of ifs that we can not honestly resolve here in 1990. The realistic cost of disposing highly radioactive wastes safely beyond a reasonable doubt may be so great that a lunar solution will become attractive.

But then, even if “the economics” became "right", there will be a host of public misconceptions to overcome - including the absurd pseudo-physics behind the opening “catastrophe” of the first episode of the much-watched science-fiction TV series, “Space 1999” in which a runaway reaction in just such a lunar repository of Earth’s radioactive wastes dislodges the Moon from its orbit around Earth, to wander through space endlessly, meeting a host of aliens along the way, of course.. But possibly such "wastes" will be the first "treasures" imported by some future Port "N.I.M.B.Y." on the Moon. < **MMM** >

MMM # 34

RECYCLING

RECYCLING By Peter Kokh

[This outline of materials-management systems appropriate for Space Frontier settlements ALSO addresses some persistent Earth-side problems.]

Recycling is an integral and essential aspect of our "tenancy" of whatever corner of the universe we occupy. It is custodial common sense. And if it is becoming sound economics here on Earth, it will be an absolutely vital cornerstone of economics on the Space Frontier.

ORGANIC & SYNTHETIC MATERIALS

First we'll need to recycle organic and synthetic materials derived from such volatile elements as hydrogen, nitrogen, and carbon which will not exist in the all-surrounding abundance we are accustomed to on Earth, even after we are able to supplement the vanishingly meager lunar sources with supplies from volatile-rich asteroids and comets. This self-discipline will be indispensable for Lunar Settlement, and highly advised for Space Colonies in near-Earth space.

Keeping the ratio of native lunar vs. exotic imported content as low as possible will alone allow any chance for a favorable trade balance and economic self-reliance. Thus priority must be given to our food and clothing needs in using these precious elements. The purpose of such an effort is to provide the lowest Cost of living, by stretching the service life of any volatiles imported at great expense and by reserving them for uses for which there are no substitutes.

INORGANIC MATERIALS

Contrary to intuitive expectations, it will also be salutary to recycle processed inorganic materials since they embody considerable energy expense already invested in extracting and processing them from raw regolith soils. The more energy-intensive a refined material is, the more to be gained from recycling it. Proper pricing of virgin materials will guarantee this outcome.

Tailings also embody the energy investment of their by-production, and using them to make secondary building products would capitalize on this investment. [See "TAILINGS" MMM # 25 p. 5. May '89 - republished in MMM Classics #3] Even glass cullet and ceramic shards can be used e.g. embedded in glass matrix decorative panels covers, fronts, handles and knobs. In the case of inorganic materials the purpose of all this effort will first be to reduce total energy-generation requirements, a strongly economic motive. Secondly, it will help settlers to minimize the Acreage of surrounding moonscape that will need to be disturbed to maintain there a population of a given size, an aesthetic goal. This "discipline" will allow us to tread softly and caringly on the magnificent desolation of an adopted virgin world.

Our strategy for realizing this authentic way of life will have many subtargets. Appropriate product design, easy sortability, convenience, collection nodes, routing and route servicing, divi-sion of responsibility, supply versus demand volume-matching, entrepreneurial opportunities, youth and school involvement, contests, public discipline, tax incentives, and backup systems must all be given special attention.

RECYCLING - FOUR BASIC PATHWAYS

(1) REUSING all refillable bottles and containers is the most obvious and most economic.

(2) RECASTING by crushing, shredding, melting, and then recasting fresh items is another. We do this with paper, aluminum, and plastics for example. This method is greatly hampered by unnecessary cross-contamination with durably-bonded unlike materials. As for markets for recycled temporary-use items, building products/ furnishings best match supply.

(3) RETASKING or use-reassignment is a greatly underutilized third avenue. Timid examples are jelly jars designed for long reuse as drinking glasses and butter dishes designed to be reused as refrigerator ware. There have been at least three abortive efforts to design what has been termed a "world bottle", a glass beverage bottle ingeniously shaped to serve anew as a brick or building block. That is one task worth taking up afresh! Designing smaller high-fashion glass bottles for infrequently sold items, such as medicines, fragrances spices, etc., with a female-threaded punt on the bottom to match the male-threaded neck would allow combining these into stylish decorator spindles for any number of imaginative uses.

Formulating packaging and packing materials to serve as craft stuffs for artists or even as fertilizer for gardeners is a promising possibility. In any such dual purpose design effort, it will be critically important to find reassignment uses with adequate demand-potential to match, and use up, the full volume of supply. Otherwise any such efforts will be but futile and distracting gestures.

(4) REPAIRING is one avenue increasingly being abandoned because of high labor costs. Repair costs, however, could be greatly reduced by more careful product design with greatly increased attention to assembly sequences and methods that are take-apart-friendly.

The present quest for seamless sophistication in appearance is one of several sirens luring manufactures in just opposite direction.

To repairing, we might add **refinishing and totally fresh makeover**. Even where repair or refurbishing is impractical, if the item in question cannot be economically disassembled, then the sundry parts that would need separately recycling will end up being irretrievably trashed.

Only the adoption of design and manufacturing methods not now in favor will make all this viable. Lunar manufacturers will need to sing this new tune. And frontier settlements cannot in the long run afford to import Earth-made items not knock-down friendly. The extra cost of meeting these new requirements will be minor in comparison with Earth to Moon up-the-deep-gravity-well freight charges.

INSTITUTE FOR MOON-APPROPRIATE INDUSTRIAL DESIGN

No amount of recycling discipline on the part of our hardy pioneers will work without such a wholesale redesign of consumer goods. For this reason, we really do need to start now by establishing an Institute for Moon-appropriate Industrial Design. While aimed at meeting demanding frontier requirements, the very constrictiveness of this challenge should make such an Institute the prestige Alma Mater of choice for industrial design students the world over, regardless of whether they had any intentions of ever leaving their comparatively soft Earth lives behind.

INDUSTRIAL ENTERPRISES

The significant upfront role of industrial enterprises in creating a material culture in which much more extensive and thorough recycling is possible than in our current American experience, is not limited to proper product design. It should be the highest priority of Frontier Governments, to provide encouragement and incentives sufficient to ensure that the principal avenue of industrial diversification involve new enterprises wins the byproduct materials of those already in place. Again, this compounds the productivity of energy already spent.

Properly integrated industrial parks will involve suites of industries in an ecosystem of traded byproducts. In one highly successful entrepreneurial effort in Texas a few years ago, an enterprising computer buff went from plant to plant, asking for data an any unwanted supplies, scrap, and byproducts to put in his data bank. Within the first year, he was able to generate enough networking between sources of previously unadvertised supply and potential customers to take in a cool $5 million for himself.

"With a good system, even those who do not care, will do the right thing. Without a good system, even those who do care, can’t do the right thing."

Given goods that are separable, sortable, and economically recyclable, the consuming citizen will at last have an honest chance to do his/her part. But it is not enough to know what should be done. Both citizens and government must also realize that without proper organization, on several levels, it won’t happen.

SORTING

"A place for everything and everything in its place" is not only an unbeatable philosophy for managing one's basement, attic, and closets. It also applies to the home and business recycling corners. Instantly identifiable bins or baskets must be conveniently arranged for every category to be sorted separately. There is no reason that home recycling centers have to look untidy, a hodgepodge of Rubber Maid baskets and paper bags. A top priority household product should be some sort of bin-susan or bin-rack setup. Why entrepreneurs aren't turning such things out here and now is beyond my comprehension.

On the Space Frontier we'll need a greater number of different bins than we do here, where the economy is only organized to take in paper, glass, aluminum and some plastics. [Milwaukee's Pollyanna Plastics is now negotiating with area recyclers to take all the vinyl bottles and (!) polystyrene foam packaging they can buy back from the public, in addition to PET and HDPE plastics.] Glass and glax*, ceramic shards, and the various metals; refillables and tradables, used cotton cloth, fiberglass fabrics, thermoplastics, paper stuffs, dye stuffs, plus various compost categories all need separate bins.

A collection system with convenient nodes to see that all these items find their way back to the industries that can use them, is the next equally critical and indispensable element in the recycling triangle. Perhaps the electric delivery vans of the settlement could belong not to individual merchants but to materials circulation enterprises. They would pick up appropriate categories of disowned goods even as they deliver, a prerequisite for a license.

ALTERNATIVES AND OPTIONS

But there must be many alternative routings to make a system work. If containers and packages in which shoppers bring things home are designed to collapse or nest compactly, they could be reused conveniently. It might even be bad taste to leave home empty handed! Drop-off Centers could be conveniently central to each shopping area. Properly arranged and managed (a place for everything, remember?) they needn't be unsightly. Featuring lockers, public toilets, cafes, they could include floral gardens, stalls for artists and craftsmen, repair and makeover shops etc. And why not arts & crafts classes, street music, dress-up fashion and bauble shows, and even a "soap box" for those eager to share their concerns?

COTTAGE INDUSTRIES

"Scavenge and Trade" licenses could be given preferentially to those with cottage industries based an giving new life to cast-off materials and items. Art du Jour, serendipitous temporary sculptures made from collected items, could be a major draw. Such creations might feature those items and sort categories for which the supply exceeds demand in the hope of stimulating would-be entrepreneurs and artisans to discover fresh unsuspected possibilities in such over-available stuffs. Demonstration classes in art-crafts using recycled and discarded items would be in order.

In Space Frontier pioneer towns, "recycling" may finally 'come out of the Alley"

Farm-Mart Centers, wherever grocery shopping is done, should not only take in the appropriate refillable containers but also buy/sell sundry categories of compost and composting accessories such as paper stuffs (e.g. corn husks) and garden and kitchen scrap dye stuffs, bone, and fat could be handled separately from any compost that exceeds home garden needs.

Jailed inmates could do the heavy duty labor intensive disassembly work; pardons might be in order for those demonstrating their capacity to function as useful citizens by entrepreneurial development of markets for orphaned and high surplus sort categories clogging the network. Primary and Secondary School involvement will be crucial in making the system work. This is the subject of the next article. [see "The 4th R" just below]

ROLE OF THE UNIVERSITY

Finally, the frontier University has a role to play as orchestra leader. The University, not govern-ment bureaucracy, must assess how well the system is working, and develop needed improvements.

A University office would maintain the computerized current inventory of various depositories with a disciplined materials accounting system monitoring supply/demand imbalances, and circulation efficiency, assign identifying sortation logos and routings for new classes, and maintain updated guidelines on a utility cable channel (or website).

The University should supervise and assist entrepreneurial experimentation in its labs and shops to develop new materials and products that will take advantage of various kinds of discard stuffs that are in excess supply. As such it will be a principal incubator of new businesses and economic diversification.

The University's **Institute of Industrial Design** would work to find new ways to implement such philosophies as "whole sheet" scrap-less design of product/accessory combos, "kosher" assembly of unlike materials for later ease of separate recycling, "honest surfacing" that utilizes the design advantage and character of materials undisguised by surface treatments that make proper sorting identification anything but easy.

VOLUME REDUCTION STRATEGIES

Not only must we provide for proper sorting and routing of items to be recycled, we must take care that the system is not overwhelmed. Volume reduction strategies are in order.

In the USA, packaging materials constitute 40% of trash.

In MMM # 4 April '87 "PAPER CHASE" [republished pp. above] we pointed out that wood, paper, and plastics will be prohibitively expensive. This whole fascinating topic of how to service the diverse packaging, labeling, and even the advertising needs of the settlement with minimum reliance on precious volatile-rich materials, that should be reserved to increase the mass of the biosphere "flywheel", will be the subject of a separate article in a later issue of MMM.

SUMMING UP:

We must not allow either Lunar or Space Settlements to be "born addicted" to a technology and culture of abundance and waste. All those elements needed to make this ambitious program work must be developed beforehand, pretested and pre-debugged before lunar settlement begins.

It would be best if as much of this as is appropriate could even be ready to go for the first NASA/International Moon Base. Those of us interested in off-planet settlement must begin the cooperative addiction-treatment program that will enable such a propitious fresh start, as well as create spinoffs that will aid in Earth's own environmental struggles.

Beating this addiction, from which we all suffer, will require a "wartime" dedication and inventiveness. Only to the degree we succeed will we prove ourselves worthy citizens of Earth's con-solar hinterland. < **MMM** >

“The Environment” - whether on Earth or on the Moon
It’s a question of pay now, or pay much more, later. **MMM**

THE FOURTH 'R'

THE FOURTH 'R' By Peter Kokh

Here on Earth, we imagine we can afford the luxury of continued general ignorance of the way our Biosphere works and what may be necessary to maintain its health. We allow our young people to drop out of school, and allow those who do complete their courses to graduate with empty heads. We assume Mother Earth will go on taking care of itself as it has from time immemorial. Those that want to worry - that's fine, let them do their thing. The rest of us - let's party!

In the miniature oases of life that Ecotects design, build, and seed with life on the Space Frontier, we will have no such luxury of aloofness or ignorance. Whether we prefer to live in space colonies, in lunar settlements, in pioneer Martian towns or elsewhere, the carefully set-up envelopes of Earth-life, water, and atmosphere we'll need to coddle our existence beyond our native womb-world, will have minimum tolerances for healthy functioning. The ecological facts of-life in the fragile exclaves of Gaia-Humanity will be immediate in their critical importance.

> A Space Frontier Biosphere or Oasis might be described as a closed mini-world where everyone "lives downwind and downstream from themselves".

This means relentless vigilance in keeping the water and air clean beyond any standards set on Earth. Food chains will be short or telescoped. And waste biomass and organic materials must be efficiently and quickly recycled.

To keep low both energy consumption and the need to radiate excess heat, we'll need to get the most product per energy input/heat-output as possible. Recycling, which recycles the energy of original processing as well as goods themselves, will be essential for all classes of materials.

Back on Earth, environmental consciousness is rising and is now the highest we've ever known. Yet, polls show people only care enough to want "someone else" to take care of the problem, and to do so without causing any personal inconvenience or forcing unwelcome changes in lifestyle.

It should be clear that if any such attitudes were common within a Space Frontier Biosphere, an environmental catastrophe most likely without hope of recovery, would follow all too swiftly. Nor will it be enough to have "a high level" of individual responsibility. Everyone within such frontier communities has to be "oasis-wise". It must be Second Nature to the Pioneers to live as if the dawn of the next day depended upon their rigorous respect for the Biosphere-Facts-Of-Life. For indeed, we'll survive one day at a time.

The only way to guarantee an oasis-wise citizenry, is to teach "Eco-Sense" to the children, not as an elective, nor as a mere requisite for graduation that can be put off to the last minute, but as one backbone of their education. Recycling - of the air, water, and biomass; of organic, synthetic, and inorganic materials - must be as important as Reading, (w)Riting, and (a)Rithmatic. Children must be taught Recycling as the Fourth "R"! Eco-responsibility has to become second nature. For if it is something we have to "remember" to do, we'll only do it when it's convenient or when someone else is looking.

Space Frontier Schools will have then a major role to play in guaranteeing the survival of the settlements they serve. The pioneer youth must learn not merely how to sort discarded items properly, but have a good understanding of how used air, water, biomass, and the various sorts of consumer materials are each routed back into the system upon which their shared lives depend. They should understand the raw materials and byproducts interdependence of industries and the interrelatedness of all those kinds of life that make up their mini ecosystem.

Students could be assigned recycling chores appropriate to their grade level to give then hands-on appreciation of how things work. The goal is not merely to produce good consumers and insure oasis-wise home-economics, nor merely to produce good entrepreneurs, industrial managers and workers, but to ensure that each citizen has sufficient appreciation of the Biosphere-Facts-Of-Life on which community survival depends, to vote intelligently and support only responsible political efforts. For while "lunacy" can be tolerated on Earth, there's no place for it on the Moon itself, or elsewhere in space.

PRIMARY SCHOOL

In Primary School, rote learning of the types of things to be sorted and recycled separately, of their names, identifying clues, and routes by which they are cycled back into the system, and of the current market uses of recycled items can all be gradually introduced. In art classes the students would use only oasis-wise media and craft stuffs, coloring agents, and finishes.

In frontier homes children could gradually be entrusted with the responsibility to monitor and manage the recycling chores within their households. They should be introduced to kitchen and garden composting, learning which food or garden scraps need to be treated separately. They can be encouraged to make things of pride from materials and discarded items.

No small part of early education would be to equip youthful vocabulary with sets of keywords and phrases having strong positive connotations. "Trash" and "Wastes", words of ill-repute, could be replaced with "Freed" used as a noun i.e. stuff relieved of previous service and ready for reassignment. ("Tommy, please drop off the freed on your way to school.") The rehabilitation of "alley economics" must start with the young.

HIGH SCHOOL

At the High School level the entire curriculum should reflect Biosphere-Facts- Of-Life. In the teaching of Biology, attention should be given to natural air and water cycles and the steps at which these processes may need assistance within the mini-biosphere. The time it takes to biodegrade biomass waste and various types of organic materials should be covered. Not only should the Chemistry of atmospheric gasses be taught but also the nature of toxins, how they are produced both-in nature ad industry, and they can be neutralized or prevented.

In teaching Import/Export Economics, the very critical role of recycling volatiles and already embodied energy must be stressed. An honest "Materials Accounting System" ought to be taught with its corrective affect on Financial Depreciation and Expense Accounting. And as an ongoing class chore/project, the economics class could maintain a Computer Database on some subset of recyclables under supervision of the University.

In industrial arts the concept of Whole-Sheet Scrapless Design can-be-brought home with school contests ad competitions. Entrepreneurialism in the service of recycling can be encouraged by the J.C.s and in Junior Achievement projects, stressing the use of recyclables for which the market is slow. Industry could provide school art classes with access to slag type sources of "accidental art" to be mounted or set for sale.

A very useful Extracurricular Activity, with supervision, would be to take in worn, broken, parts-missing, and cast-off small durable items, especially including toys. These could then be repaired and rehabilitated. And where this is impractical, the items could be disassembled so all materials needing to be recycled separately, can be. Time can be allotted for "Serendipity" ephemeral sculptures from such parts.

UNIVERSAL CIVIC SERVICE

Nor should this "immersion" in the spirit and process of oasis-wise recycling stop with graduation from high school. In space frontier communities, where there will always be more to do than people to do-it, a Universal Civic Service after high school might not be a bad idea. Manning and maintenance of streetside recycling nodes, with care for their attractiveness and efficiency, operating other nodes in the recycling system, and other "schlepping" chores such as accident cleanups and maintenance of Parks and alleys are one way a “Citizen-Candidate” might pay his/er dues to frontier society.

Biosphere Maintenance is another appropriate dues-paying activity: i.e. manning the water-treatment and air-freshening facilities, various yeoman farming duties such as sorting spoiled produce and other biomass "freed" into mushroom matrix, animal fodder, and general compost.

Apprenticeships in the trades using recycled materials might also be considered for citizen-candidates if there are not enough of the above-listed job slots available. Cleaning refillables and other labor-intensive duties in the various recycling chains may also be in order.

The grand result of this thorough three step education process (primary and secondary schools followed by a stint of universal civic service) would produce Space Frontier Citizens who fully appreciated the fragility of their particular oasis of life and who forever remained deeply predisposed to live and act in a oasis-wise manner. We might even put some of these education ideas to use right here on our home planet.

MMM

MMM # 38

Concepts of Regolith Primage

PRIMAGE

A “Do or Die” Key to Lunar Industrial-Agricultural Success

By Peter Kokh

The pre-tilling of the Moon

Concepts of Regolith Primage

Through eons of meteorite bombardment, lunar soils have been extensively "gardened" or turned over vertically, and even mixed horizontally - up to half the surface materials in any given area is the import of splashout (impact ejecta) from areas nearby and distant alike. On Earth, mineral-based industries have been able to take advantage of enriched and concentrated deposits - a result of eons of geological processes peculiar to our planet. While undoubtedly somewhat more favorable concentrations of a few minerals do occur on the Moon (homogenization provided by bombardment not being 100% thorough), in general lunar settlers will have no choice but to make do with deposits we would shun as "uneconomic".

While the Moon is richly endowed, in a gross sense, the lunar economy will have the much more difficult job of separating out or beneficiating the desirable minerals prior to processing. No one should imagine that just any system of lunar mining-based economy would guarantee success.

In "Gas Scavenger" [MMM # 23 p.4 March 1989 - republished in MMM Classics #3] we pointed out that if we religiously extracted the pure iron fines and all the Solar Wind deposited gases from any and all regolith that we had to move or handle anyway, we would then accumulate potentially valuable reserves, at low cost, that could be one principal means of diversifying the settlement economy. We have to move regolith in excavating for shelters,

in covering them with shielding, in grading roadways, and in providing raw materials to ore processing facilities. Iron fine removal (by magnet) and gas extraction (by heat) capabilities should be an integral part of ALL regolith-moving equipment, we counseled.

Agricultural Needs

Let’s carry the argument further. Apparently, some of the things that worry lunar agriculture researchers most, are actually characteristics of 'gross' lunar regolith easily changed in the handling process. After all, settlers won't be erecting domes over undisturbed lunar regolith, then attempt to farm this raw soil. We will be building pressurized agricultural modules of whatever volume - and then, moving regolith from the outside into the prepared beds within.

Researchers worry that the 15-20% fraction of regolith which is ultra-fine powder of less than 0.25 mm grain size, fine to medium silt, will clog soil pores leading to water-logged soil. In the Moon's light 'sixthweight', water will percolate through the soil more slowly; thus we will want somewhat coarser soil than is ideal on Earth. In the course of bringing regolith- soil in from the outside, this fine silt can be removed by vibration-sieving or by 'winnowing'. As a bonus, this unwanted fine silt may have a higher content of adsorbed Solar Wind gases; also it may be easier to process in some ways (glass?, ceramics? etc,) than less refined 'as-is' regolith.

The 75% ideal medium-sand-through-coarse- silt 1.0-0.25 mm fraction is next. A 3rd sieve removes larger agglutinate glass nodules which can then be transformed into zeolites by mild hydrothermal processing [150^o C, 0.3 MPa, 76 h]. Zeolites are hydrated silicates of aluminum with alkali metals (K, Na) and cavity-rich crystal lattice structure. They can be used as catalysts, adsorption media for gas separation, insulation, and molecular sieves. And added back into the “soil,” they will enhance mineral ion transport to plant roots, especially in early 'immature' soils not yet fully colonized by micro-organisms nor laden with organic matter. How to provide for sufficient mineral ion transport in regolith-derived soils is thus another needless worry on the part of researchers. [In view of these possibilities, I am rather critical of the value of lunar agriculture experiments that use any lunar simulants formulated on the unexamined presupposition that we will be stuck with using crude raw regolith.]

The remnant after this last sieving operation would be larger rocks (aggregates and breccias) that could serve well as gravel fill, for lunar concrete. So, just by including this multi-step vibra-sieving operation in our "Regolith-mover", we will have (1) enormously enhanced the chances of success for lunar agriculture; (2-5) started businesses in molecular sieves, gas-separation, catalysts, and insulation; (6) supply the highly refined material needed for processing; and (7) supply coarser material for 'lunarcrete' mix.

A third worry of the Lun-Ag people is potentially toxic levels of chromium and of nickel in regolith-derived soil. Their concern is perhaps more justified with chromium, as observed nickel concentrations are possibly tolerable. How we could make use of regolith pre-handling opportunities To extract a significant fraction of the Chromium-containing minerals (e.g. some spinels) is a nice challenge for the chemical-engineering types among our readers. How about it?

A Tool for Many Needs

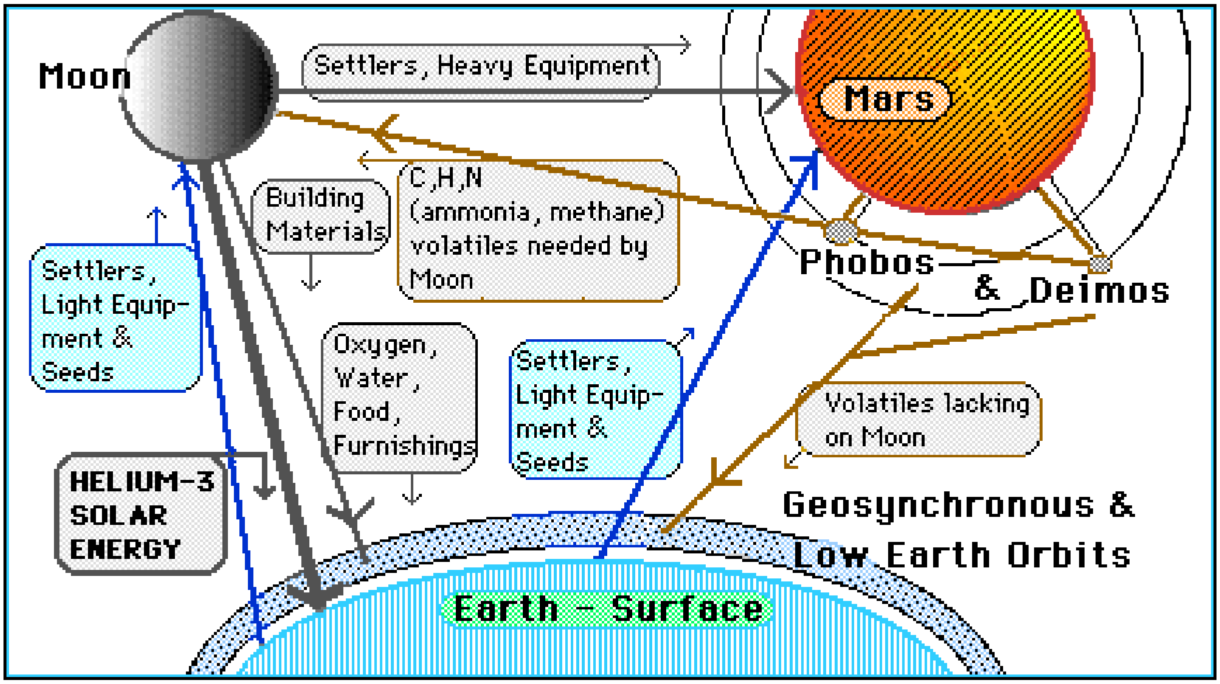
Now that's quite a work load for our everyday Lunar 'Lith-Mover! Iron fines; Solar Wind gases; silt for processing; Ag-grade soil; zeolite feed stocks (glasses) for agriculture filtration and insulation; gravel for lunacrete; chromium ores. We can obtain all these in the very handling of regolith, prior to all other forms of processing - including oxygen-extraction and glass-glass composites (Glax) production. For these collective First Fruits, I propose the term "Primage." [Most dictionaries define this term solely as a safe-handling bribe paid by a shipper to ship's captain and crew. But as a suggestive precedent, the O.E.D. also has: "the amount of water carried off suspended in the steam from a boiler" (about 3%)]

A Primaging 'Lith-Mover

Going through all the bother of careful regolith-primage, much like scraping and sanding the loose paint before repainting, will seem to most a thankless and unwelcome ritual. There will be a strong temptation to dismiss the need. But the settlement that adopts primaging as a transcendental imperative, will have a significant head start towards economic diversification and self-sufficiency.

Primaging could be the well-spring both of prosperous lunar industry and of productive lunar agriculture. Developing a practical, simple and rugged "Primaging 'Lith-Mover" should then be among our very highest priorities.

MMM



How an Earth-Moon-Mars Economy might work

What gets shipped where depends on the price delivered, and unless time is of the essence, shipping costs can be the decisive factor. There is an up and down in space if you consider gravity wells. The deeper the gravity well, the more fuel it takes to launch out of it.

Anything lunar settlements make for themselves will be cheaper to ship to markets elsewhere in space than equivalent products made on Earth. Thus lunar building materials and furnishings and other items made for lunar pioneers could well find themselves in low Earth orbit and Geosynchronous orbit stations, hotels and resorts, industrial parks, etc. Such exports would help pay for things made on Earth that could not easily be produced on the Moon.

The biggest market might be building materials for solar power satellites, power relays, and multi-satellite platforms, all in GEO.

The diagram also shows how Mars could fit in with its two moonlets Phobos and Deimos playing a key role. As it turns out all space destinations have a better chance to thrive and prosper as mutual trading partners than any of them would on their own. So it is in the Moon's interest that a Mars frontier be opened, and vice versa. The asteroids will plug in to this trade network in turn. MMM

MMM # 40

CLOACAL vs. TRITREME PLUMBING

CLOACAL VS. TRITREME PLUMBING By Peter Kokh

The Best Plumbing System for Lunar and Space Settlement Biospheres?

cloaca: (clo AH ka) = a common cavity into which the intestinal, urinary, and reproductive canals open in birds, reptiles, amphibians, and monotremes (the lowest order of mammals).

monotreme: (mo NO treem) = either of the two remaining species (duck bill platypus and spiny anteater) of the lowest, most primitive order of mammals, with one hole for all discharges.

SCENE: the lower Indus Valley about 200 miles NNE of modern Karachi, in the north part of Sind province, in what today we know as Pakistan.

TIME: some 4,000-4,500 years ago.

PLAYERS: a people, long since vanished from the area, but with increasing evidence that they were the ancestors of the populous dark-skinned peoples of today's southern India: the Dravidian speakers of Tamil, Telugu, Kanarese, Malayalam.

ACT I: fade from the ruins we see today, and known to us as Mohenjo Daro, back in time to one of mankind's first experiments in urban settlement - we do not know by what name its inhabitants called it - where the city fathers meet to accept the plans of their chief urban architect for the world's first urban sewer/drainage system: a network of gravity-gradient open ditches, into which all liquid-born wastes would flow off to same final place of out-of-sight/ out-of-Mind.

ACT II: there never has been an ACT II. Ever since Mohenjo-Daro, except for putting the sewer and drainage system underground and treating the effluent so that it commits less aggressive harm against neighboring communities, we have been in the rut of the very primitive duck bill platypus, stuck using a cloacal system to handle the quite different wastes from toilet (septage), bath and laundry (gray water), kitchen, and industry. Lessons for the “New Towns” of Space Except in "new towns," it would be prohibitively expensive to switch to a new 'multi-treme' system which keeps different types of sewerage separate from the beginning in order to benefit from simpler and more efficient source-appropriate forms of treatment, with the fringe benefit of enjoying whatever valuable byproducts such separate treatment may promise. Lunar and space settlements are "new towns". Infrastructure is 'change-resistant'. Therefore it is of supreme importance to choose it wisely from day one.

While in many other areas NASA has chosen to pioneer radically new technologies, the agency, and those involved in the 1977 Space Settlement Systems Summer Study, turned instead to existing urban models when it came to the basic architecture of plumbing and sewerage treatment systems. If you think of the opportunities for Earth-side spin-offs, this decision emerges as a major slip-up.

Let's explore the benefits of an alternative triple conduit or tri-treme drainage and routing system for future off-planet mini-biospheres.

1) Farm, garden, and lawn run-off, food processing waste and kitchen garbage disposal waste (if not saved to compost for home gardens): the water laden with them should be kept separate by a distinctively labeled and color and/or design-coded drain and conduit system. After sieving out larger chunks for composting, such water can empty into fish tanks without further treatment.
2) Gray water from showers, hand/dish washing, and laundry would similarly have a privileged routing system, to a treatment facility which would remove whatever biodegradable soaps and detergents are allowed, for composting separately. The remaining liquid could be run during dayspan through shallow near-surface ponds, top-paned with quartz, where 'raw' solar ultraviolet would sterilize it, killing all pathogens and bacteria. Simply cleansed and purified with the biodegraded cleaning added back in, this nutrient-rich water could go directly to farming areas and into the drip-irrigation system.
3) Septage (urine and feces) can be handled next in several ways. The familiar very water-intensive water-closet flush toilet system could be preserved, connected to its own drainage net. Solids could be removed to be channeled through an anaerobic digester for composting and methane production [see "Methane" below], and suspended particles in the waste water treated by microbes to produce milorganite type organic fertilizer. The clarified effluent would then go to the farm watering system. Or, the urine and fecal water might alone use a third drain line system, while fecal solids are 'collected' for separate treatment. [See "Composting Toilets" below].

4) Industrial effluent must be purified and reused in a totally closed on site loop with a high price for any loss-makeup water piped in. Allowing industries to discharge water, of any quality, into the public drains system, invites passing on cleanup costs to the public. If all industries must play by this rule, and cost out their products accordingly, there will be no problem with this make-or-break provision.

The 1977 NASA study recommended the use of a wet-oxidation (euphemism = incineration) process for treatment of all water-carried wastes indiscriminately. While this method almost certainly offers the swiftest turn-around for our costly original investment of exotic (= Earth-sourced) hydrogen, carbon, nitrogen, and possibly added phosphorus and potassium, on the order of 1-1.5 hours, it misses valuable and elegant opportunities to produce 'organic' fertilizers and other regolith-soil amendments far superior to chemicals in their buffered slow-release of nutrients and in soil conditioning character.

In smaller space and/or lunar outposts, heavy reliance on chemical assistance for fast-cycling sewage treatment may be the only feasible way to go. But as we design settlements for hundreds or more pioneers, we have the opportunity, if not the duty, to consider more natural alternatives. Every part of our proposed tritreme drainage and sewage treatment system, has separately received abundant proof of concept on Earth. **MMM**

MMM # 41

Introducing MMM's new Vision Statement

"Expanding the Human Economy Through Off-Planet Resources"

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

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

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

MMM # 65

The Fast Road to Lunar Industrial MUS/cle

And the "Substitution Game"

By Peter Kokh

“MUS/cle” is a mnemonic acronym we coined in a previous article on Lunar Industrialization strategy in MMM # 18, SEP ‘87 pp 3-4. The first syllable **MUS** endeavors to point out the type of products it is appropriate for a small lunar outpost to try to make in an effort to cut down on the tonnage of imports needed to support its existence. “**M**” stands for massive items and components, “**U**” for unitary items or things manufactured in large quantities, “**S**” for items that are fairly simple in design and manufacturing process. Sometimes an item will be M, U, and S all at once, sometimes not.

The “**cle**” syllable, usually in small letters to get across that this suite of items represents much less aggregate tonnage, endeavors to point out the type of things that are best left to Earthside manufacturers because they are “**c**” relatively complex in assembly and require sophisticated manufacturing from a host of parts and subassemblies supplied by a large number of diversified subcontractors, and/or “**l**” lightweight, at least by comparison, and thus much less burdensome for the settlement to upport out of Earth’s gravity well. Such items often include “**e**” electronic components or assemblies.

Such a MUS/cle strategy for deciding what the young settlement should try to self-manufacture and what it should rest content to upport is absolutely necessary. Space advocates talk frequently about settlements becoming self-sufficient or able to pay their own way. But the cold fact is that while in simpler ages, now irretrievably long gone by, smaller towns could make most of what they needed, in today’s increasingly technical civilization, it is estimated that a city has to have at least a quarter of a million people (250,000) to be able to support an industrial base sufficiently diversified to satisfy 95% of its own needs. Self-sufficiency is an asymptotic goal, of course, one which (like the elusive speed of light) requires exponentially more heroic effort to continue closing the gap the closer one gets to it. Thus, for example, a more modest goal of 60% self-sufficiency might be achieved by a town of only 25,000, just 10% as large (to grab a figure out of the air).

While the law of diminishing returns must eventually step in to make further efforts at self-sufficiency unrewarding, it will make an enormous difference in how we plan, or fail to plan, expansion and diversification of the lunar industrial base. “MUS/cle” gives us a serviceable rule-of-thumb guideline.

Following this guideline, we need first to look at the list of material items our settlement will need in terms of gross tonnage per item. Obviously shelter is at the top of the list. But included in the upper ranks are many other things that can be made of the same indigenous “building materials” suite needed to make shelter (metal alloys, glass, glax, ceramics, Lunacrete) namely tankage for volatiles, vehicle body parts, furniture, utility system components, etc.

Now the “Tonnage Of Imports Defrayed” [**TOID:** a Lunar Accounting Term on the same side of the Balance Sheet as our “Retained Earnings”] is not our only consideration. It is also extremely important to see that scarce lunar person-power is used as productively as possible. This will mean not only output per person (a “ton of dishes” over a “ton of computers” as a goal for self-manufacturing) but rather more significantly, **exportable output** per person. It reinforces our belief that “MUS/cle” puts us on the right track that many “MUS” items and components self-manufactured on the Moon for settler’ use are also high on the list of potential moneymaking exports to markets in Earth orbit, L4 & L5, expeditions to Mars and the asteroids, etc. We’ll talk more specifically about exports in the closing installment in this Lunar Industrialization series.

The “MUS/cle” paradigm will not take us too much further than this if we limit it to ‘whole’ items. “Phase II” (logically; in fact it must be implemented alongside Phase I from the very outset) is to look at every more complex item that the settlement needs and see if it can be broken down into “MUS” components for local manufacture (example appliance cabinets or casings) and “cle” parts for shipment from Earth.

“MUS/cle” Inspired Industrial Design

To maximize the potential, it may well be necessary to do some serious industrial redesign of the items in question to better segregate and maximize the potential "MUS" components, and to better integrate the remaining "cle" components in "works cartridges" for subsequent labor-light mating and assembly on the Moon. This may seem a costly burden for Earthside suppliers. But forces now at work are slowly forcing industrial designers to rework their products even now. In Europe, it is becoming the law that manufacturers must buy back their own products (once they are unwanted) for recycling. In order to make recycling easier, these products are being redesigned so that they can be easily disassembled into various types of recyclable components. "MUS/cle" provides a compatible and enhancing guideline for industrial designers, and is especially appropriate for today's multinationals who manufacture components all over the globe. So "MUS/cle"- inspired Industrial Design is a promising **career choice** for one motivated to do his/her part to push the opening of space.

The "MUS/cle" Program can be 100% Retroactive

The cynic will say that there is no hurry here because the settlement will not be able to supply the potential "MUS" components for some time. So we might as well save some money and ship ready-to-use items as we now have them. Such (any!) cynicism per se blinds its slave to opportunities. While the above assertion is undeniable on the face of it, it is in fact only half a truth.

IF we go ahead with "MUS/cle" redesign and then, while awaiting the step by step growth of Lunar industry, build ALL of the item on Earth, **but** manufacture the "MUS" component out of metal or volatile elements which the lunar community cannot, or not yet, economically extract from the available regolith soils, we will be shipping to the Moon not only a needed item, but, as a relatively cheap bonus, providing a "**yoke sack**" of Lunar Deficient materials. Once the settlement can self-manufacture the appropriate "MUS" parts, the original Earth-made parts can be cannibalized for their content as they are eventually replaced. Such endowments will enable the settlers to make an end run around their deficiencies.

"MUS/cle" is a radical growth strategy to guide the planners of lunar industrial diversification in setting priorities and schedules. More, it is a strategy to radically filter the design of anything and everything that is shipped to the Moon from day one on. At first the payback will be but a promise, but eventually, religiously pursued, the "MUS/cle" strategy will outperform any savings bond. "MUS/cle" must be a key instrument in the "Bootstrapper's Toolbox". **MMM**

MMM # 66

ENCYCLOBIN INC.

Letting the Right Hand Know

What the Left Hand is [by]doing

"A question of not wasting spent personpower"

By Peter Kokh

Making the most of energy and personnel will be very important anywhere on the space frontier where existence must be eked out in barren surroundings untransformed by eons of living predecessors. Support from Earth will be dear, no matter to what cost/per kilogram launch expenses fall. To waste no import crumb, to put to best use every scheduled productive hour, to get the most out of the talents of available personnel, it will be vitally important to keep track of things of which we are by habit oblivious in our terrestrial “business as usual”. The settlement with the cavalier attitude towards loose ends will fail. The one that ties up those loose ends in bonus bouquets will thrive.

What is needed is a hyper-organized or multi-dimensional matrix type data base in which the settlement can keep track of every gram of reject and byproduct and waste in every category of material from all its industries and enterprises. Any enterprise would be able to access this resource bank and find out which of its needs is available, where, and for how much. Any discarded material has already had work done on it - if only the sorting, and putting that expended work to profitable use, instead of losing it in a default waste regime, will enhance by that much the net productivity of the community.

Relatively unprocessed tailings, partially processed slag, fully processed reject material; solids, liquids, gasses, even waste heat: these are all things worth keeping track of if one wants a leg up on the formidable odds against success of the settlement. Such items can then be banked where produced or moved along specific routing channels to some surplus commodities exchange warehouse. Purchases can be direct two party affairs or mediated by the utility as a special broker.

Using “partially cycled” or “precycled” items makes as much economic sense as using “recycled” ones. It keeps down the cost of manufacturing new goods, can be the source of new enterprises, and helps minimize the material impact upon, and disturbance of, the host terrain, thereby stretching resources that future generations will need as well.

An “Encyclobin” Utility would be a publicly regulated enterprise to keep track of all such items and charged with facilitating their fuller use as potential resources. By keeping track of byproducts unwanted by each producer, it will help inform the “right hand” of what the “left hand” is “bydoing” so to speak. Personal talents, expertise, and experience ought also to be listed for help in putting together teams for new projects. Encyclobin would serve as a finder service, for which there would be a fee to help maintain and grow the system.

The **University** might run such a system to best categorize everything, trace potential connections, and suggest novel applications to enterprise. Waste not, want not! MMM

MMM # 67

Xeroprocess

Xeroprocess

xe ro- (ZEE ro): from Greek xeros, “dry”

Those planning industrial operations on the Moon might well take a page from Xerox.

By Peter Kokh

To go a step beyond the water conservation and treatment strategy of closed industrial water loops, the settlement authority can offer processing and manufacturing enterprises various incentives to design and engineer water “out of the process” in whatever use category this is practical.

For producers of metals and other basic materials to be used in lunar manufacturing, it is especially important to attempt to redesign tested and familiar methods, sometimes scuttling them altogether, to find regolith handling and sortation and beneficiation systems that use as little water as possible. For example, piped or trough-borne slurries can be replaced with simple conveyor systems. In pressurized quarters, air assists can be added, especially for separation of materials by particle size, powders from heavier grains. Vibration sifting can be factored in, especially in the unpressurized "outvac".

The alternative is to provide relatively voluminous capital water endowments to such processors, along with all the water treatment equipment to create a closed loop. Xero-processing methods could result in a significantly reduced tonnage of capital equipment and endowment to be brought to the Moon. This translates to an earlier startup for the industry in question. If it is a keystone industry, that would be vital.

Water-based chemical treatments will be more difficult to do without and in that case the used doped waters must be recovered and recycled. Yet it is certainly worth brainstorming waterless methods, one industry-specific application at a time.

It is unlikely there will soon be anything that mimics our petroleum-based synthetic chemicals industry with its myriads of sophisticated derivative products rich in the exotic volatiles the Moon lacks in carefree abundance. Such products where it proves impractical to do without them, are better imported ready to use, leaving the associated industries, their capital equipment and discharge and waste problems alike, back on Earth where they can be better handled. Thus the use of water based emulsifiers and other organic agents in early lunar industries is unlikely in the first place.

For cleaning, sonic methods may do in some uses. In others, such as degreasing, water-based methods in closed loop systems may be the only practical option – unless alternatives can be found for the occasioning use of lubricants and grease in the first place – here is the place to start in 'option-storming'.

In using fine-tuned jets of water under pressure as a cutting and shaping tool, typically relatively small amounts of water are used and simply recycled. This judgment may also apply to some uses of pressurized abrasive suspensions in surface cleaning and treatment. Still, it is certainly worth exploring xero-process methods in both cases.

For cooling, little treatment if any is needed of the used water and it can be immediately recycled. Yet other methods are certainly preferable especially if the amounts and types of heat production allow. Options include heat pipes (possibly incorporating eutectic NaK, a Sodium-Potassium alloy that is liquid at room temperature) combined with surface radiators. If the heat could be useful for application in another part of the process, or in a "next door" companion industry, this needs to be considered in a decision whether or not to use water-assisted heat transport and whether or not to tie that into a power cogeneration scheme using steam.

If the industry's processes are segregated into energy intensive and heat producing operations that can all be done in dayspan, and labor-intensive and heat absorbing operations that can be postponed and reserved for nightspan, then heat-pumping thermal output into and out of a water-ice reservoir makes sense. But as soon as a NaK production facility is on line and can meet the demand, substitution of this lunar-sourced eutectic alloy for water as a heat bank would save enormously on capital costs, translating to earlier startups and faster diversification.

Since it does come down to significant differences in required initial import tonnage and consequent time-is-of-the-essence diversification timetables and decisions, the choice may not be left up to industry. Where the settlement's indus-trial and enterprise Review Board deems it practical, xero-processing and xero-manufacturing methods may be mandated, especially if already pre-developed. Whether a potential joint venture partner uses xero-industrial methods will then also make a difference in submission of a wining bid.

And what about agriculture and food processing? In the absence of regular-enough rainfall, plants and crops must be irrigated, and salts leached from the soil must be carried off along with waste fertilizers and pesticides. At food processing facilities, produce has to be washed, cooked or blanched, and often water-packed. Each specific step and operation has to be analyzed to see if it can be redesigned for either waterless methods or at the minimum for water use methods that cut down on the total capital volume of water needed as well as make the treatment and reuse of that water easier.

Nor can we wait for any of this until we are on the Moon and it is time to add a new startup industry. If we are not prepared to hit the ground running with enterprises thoroughly redesigned for lunar-appropriate methods, then valuable time will be lost one way or the other. Either we choose to pay the piper by bringing up a greater and costlier mass of capital equipment and capital water endowment for inappropriate operations, forcing a delay in ability to import additional industries, or we tread water waiting for an industrial operation to be redesigned then - something that could have been done already.

So how do we see too it that when we need them, industries and enterprises using lunar-appropriate methods such as xero-processing are thoroughly thought out, engineered, field tested and debugged - already to go? One way is to set up an **Institute of Lunar Industrial Design**, NOW! This could be part of a **University of Luna - Earthside**, also set up now, not on the undergraduate teaching level, but on the graduate industry-subscribed research and development level. We propose to see to it that this is done, ready for its debut at the ISDC '98 in Milwaukee.

MMM # 69

Producing for Export: Bringing Home the "Bacon & Brass"

BACON & BRASS By Peter Kokh

Relevant READINGS from Back Issues of MMM

[included in MMM Classics #1] MMM #2 FEB 87 p3 "Essays in M": M is for Market

[included in MMM Classics #3] MMM #22 FEB 89 p3. "!st Exports"

[included in MMM Classics #4] MMM #32 FEB 90 p4 PRINZTON; Part VI:

C. Lunar Export Categories; D. Export Destinations; E. Strategies to Increase Exports.

Despite a dedicated "MUS/cle" program [MMM # 18 SEP '88 pp. 3-4 "Lunar Industrial MUS/cle", and MMM # 65 MAY '93 pp. 7-8 "The Fast Road to Lunar Industrial MUS/cle and the Substitution Game"] and an aggressively played "Substitution Game" [MMM # 65 May '93 p.3.]. there will still be a stubborn core of costly imports, including, most importantly, the "passage" of settlers themselves. Frontier settlements must pay this bill with the coin of export earnings. Accordingly, with all due respect to the law of diminishing returns (i.e. there comes a time when added effort does not yield commensurate reward), every opportunity to diversify exports and take advantage of new market niches must be explored.

The "Cost of Living" on the Moon may well be astronomical, measured in dollars. But the Lunan "Standard of Living" may be quite comfortable nonetheless — if Lunans can find enough ways to pay the bills. We think they can.

In theory, the export potential for lunar settlements is both much broader and much deeper than most would suspect. In reality, everything will depend upon 1) how fast the lunar economy can diversify, 2) how favorable is the climate and support structures for entrepreneurial initiative, and 3) how fast the productive sector of the settlement population can be made to grow. All three of these questions deserve articles or series of articles in their own right. We'll treat each of these topics in future issues. Right now we want to explore the potential.

Lunar Exports to other Space Markets

If the first rule of import policy is not to import more of what you already have (the so-called "no coals to Newcastle" policy i.e. the Moon should avoid importing items rich in silicon, oxygen, aluminum, iron, titanium, calcium, and magnesium) the first rule of export policy is just the reverse. The settlements must strive to exploit the potential market value of those very same indigenous assets to the fullest. All lunar development scenarios start out in this same direction. And then they pull their punches.

Let us take oxygen for our first example. It is now the common wisdom that production of liquid oxygen be given first priority. This oxygen would be intended for use as rocket fuel oxidizer to help reduce the fuel cost of imports, and to make water for the settlement by combining it with imported hydrogen in fuel cells, a process which will recover, hopefully during nightspan when it is needed most, some of the energy which went into its production.

Liquid "lunox", would not only be used for Moon to Earth travel, but could also be delivered at a substantial competitive price advantage to low Earth orbit, where it could help refuel new outbound deliveries. But this seems to be the limit of imagination in published scenarios.

By the same token (oxygen can be delivered to LEO from the Moon at substantially lower cost than it can be resupplied from the much nearer surface of Earth just below), Lunox should be combined with hydrogen brought up from Earth to make all the water used in low Earth orbit facilities: space stations; tourist resorts; orbital processing and manufacturing facilities, etc.

Pressing the advantage a step further, the cost is still more than competitive if the lunar oxygen arrives in LEO already combined with terrestrial hydrogen to make the water and protein and carbohydrate in food tissues. Of course these savings will be maximized if only dehydrated or concentrated food product is shipped from the Moon, along with the oxygen with which to make the water needed to rehydrate it. In short, there is a market in LEO for lunar agricultural products — in LEO and any other space location at which on site food production is inadequate to fill the need.

Lets extend the argument to building materials made from lunar regolith soils: metal alloys, ceramics, concrete, glass, fiberglass, and glass-fiberglass composites ("Glax"). It may well be that the biggest market for such products is in construction of space-based facilities: new and more spacious space stations, orbital resorts and factories, solar power satellites, space construction camps and space settlements etc. But just as on the Moon itself, there is a substantial secondary market for these materials in utility system elements and in furniture and furnishings, these very same items can be produced in excess of local lunar need for export to all of the above space markets.

On the Moon, the cheapest fabric will be locally produced naturally dyed [see MMM # 48 Sep 91 p. 8] cotton since it is an unrivaled 50% lunar oxygen by weigh. Given the lower fuel costs needed to bring it to market in LEO and other space sites, lunar cotton and the apparel made from it should be marketable at a real price advantage over fancier cottons and other fabrics produced on Earth. This argument extends to other cotton uses as well: upholstery material, toweling, bedding etc. Lunar grown linen will enjoy a similar advantage.

In short, the Moon will not only **build** the bulk of future space facilities, but **outfit** and **furnish** them, and **feed** and **cloth** their occupants. That's a diversified export basket!

But we can do more. There are many items that we can expect to be in demand in the various space locations but on which lunar enterprises will not soon, if ever, be prepared to enter a complete bid. Yet if lunar appropriate industries can supply some of the weightier components - according to the MUS/cle scheme - then the potential cost savings through lunar sourcing may make it attractive to assemble the needed items in space, using lunar and terrestrial components both.

We are talking about products in which "the works", the complex, often electronic, and sometimes lighter weight subassemblies that can only be manufactured by sophisticated techniques on Earth require for completion a casing or cabinet or body or support structure that is functionally simple enough to be made of a wide variety of basic materials, and often (not always) comprises the more massive fraction of the total item. These latter less demanding components can be manufactured on the Moon just as easily as on Earth. Items in this category include major and minor appliances, machine shop tools, vehicles – yes, even space vehicles. See the article "COSMOTIVE, INC." below.

Its simple, really! The same industrial "MUS/cle" strategy that can help lunar settlements minimize the total tonnage of imports they need to survive and grow, also provide them with a strategy to maximize their collective penetration of other space markets.

Lunar Exports to Space Markets
OXYGEN (air, rocket fuel, water constituent)
OXYGEN-RICH (food, cotton goods, farm products)
BUILDING MATERIALS (iron & steel, aluminum, titanium, magnesium; ceramics, concrete, glass, fiberglass, glass-fiberglas composites)
MANUFACTURED GOODS (furniture & furnishings)
COMPONENTS (tanks, shelter, vehicles, machines, appliances, and more)

Lunar Exports to Earthside Markets
ENERGY (lunar built solar power satellites; lunar solar arrays; helium-3 fusion fuel)
TOURIST EARNINGS ETC. (lunar vacations, use of lunar owned facilities and vehicles elsewhere)
MANUFACTURING LICENSES
GEOSCOPY (lunar remote sensing installations)
MISCELANEOUS (souvenier giftware, arts and crafts, movie studios, television productions)

Lunar Exports to Earth Surface Markets

None of these strategies will help Lunans come up with items to sell directly to Earth. All of those categories in which lunar enterprises can be competitive in Earth orbit and beyond will on Earth itself be far more cheaply purchased from even the most exclusive and expensive of terrestrial suppliers.

Space-based energy will clearly be the most profitable of the Moon's exports to Earth itself. This trade will be indirect in the case of solar power beamed from satellites and relay stations constructed in space largely of lunar materials. If lunar surface-based solar arrays are used, profits may be higher even if energy collection-transmission efficiency is less.

And then there is Helium-3. If fusion power becomes a major player in the terrestrial energy supply mix, and if the exploitative (in the worst sense of the term) "see-want-take" regime has been rejected in favor of "purchasing for fair value" from those who live where the supply is to be found, the percentage of profits from the energy trade that flow directly into lunar coffers could be the greatest.

A very respectable second Moon to Earth export could be tourist experiences. See the article "TOURIST EARNINGS" below. For a long time this market will be small, limited to the slowly growing "jet setter" class given to vacations that are well out of the ordinary and well beyond common means.

For those who can only dream about in-the-flesh travel beyond Earth's atmosphere, film making studios on the Moon will take in some small fraction of the terrestrial entertainment dollar supplying the Earth-bound with the vicarious second best. Lunar TV stations carrying sports events and dance spectaculars unique to the Moon's fractional gravity ("sixthweight") could someday earn a respectable portion of the terrestrial commercial advertising dollar.

Then there is income to be earned from the sale of manufacturing licenses for processes and products developed on the Moon but for which there is potential demand on Earth if shipping costs can be factored out. At the other end of the spectrum, for those who don't have to ask "how much does it cost", there will be a small luxury trade in lunar souvenirs and giftware, furnishings and fashions, jewelry etc.

Geoscopy – dedicated scanning of the Earth's surface, is an area in which lunar surface installations may in some instances be less expensive to deploy, cheaper to maintain, and less constrained by size and mass restrictions than those incorporated into Earth orbiting satellites. Interferometric remote sensing in the full range of the visual spectrum as well as in other ranges of electromagnetic radiation could become a modest money earner.

The list above is by no means either definitive or all inclusive. Yet you can see that it includes energy, materials, manufactures, arts and crafts, experiences, and services. On Earth those nations do best over the long haul that are not dependent on just one narrow export category but rather have diversified their export offerings with a wide range of mineral, agricultural, and manufacturing products – and services. It will be no different with nations whose homelands lay beyond Earth orbit. Earning too large a fraction of the trade dollar from just one item is a prescription for disaster. Such monocrop or monoproduct reliance makes a national economy vulnerable, wide open to collapse if another cheaper source is found for their one and only commodity.

It takes all kinds of people with all kinds of talents to make a society. It takes all kinds of products and services to make an economy. So too, it takes all kinds of products and services to make a healthy export base. The lunar frontier economy has this potential to fill this mold someday, and it should be able to play the game well – if lunar industrialists and entrepreneurs exploit all the aces and play all the trump cards their adopted home world offers them.

TOURIST EARNINGS

FOR SALE: Unforgettable Experiences & Unequaled Opportunities

By Peter Kokh

Profits from space tourism to be plowed back into the Lunar economy, can be earned for the Moon only to the extent that the tourist operations involved are owned, operated, and equipped by settlers. If at first this seems an unlikely scenario, consider the cost of building tourist resorts in LEO [Low Earth Orbit] from materials brought up from Earth in comparison to cruder yet comparable facilities built of materials processed from lunar regolith – the twenty-fold savings in freight charges will tip the edge to companies able to supply the latter, once the necessary upfront capital investments have been made.

Initial LEO resorts prefabricated on Earth will be small, however luxurious. Ample and spacious complexes able to accommodate a much wider range of activities (read zero-G sports and recreation) will have to await the breakthrough in construction costs promised by NTMs — Non-Terrestrial Materials. Compare 50s era Las Vegas resorts with those of today and multiply the difference by a hefty factor!

That said, earnings from the use of lunar materials to support expanded tourist opportunities in space will only flow into lunar accounts to the extent that the building materials manufacturers and construction companies involved are settler-owned and/or settlement-taxed. Unfortunately, there are ample past models for exploitative colonialist rape-theft of foreign resources to give us ample warning that without the proper legal-political-economic regime in place, space frontier settlers could well end up not seeing a penny of the profits. Indeed, some of these unsavory practices have been at least implicitly advocated in development schemes put forward by some space advocates emotionally opposed to surface settlement by “planetary chauvinists”.

Assuming that we set things up right however, the construction, outfitting, and servicing of tourist facilities in LEO should provide a major market for the lunar economy. After all, tourists are the one thing it is far more profitable to source from Earth than from off-planet! And LEO is their handiest, least expensive “off shore” destination.

“Build it and they will come” — for the rocket-thrust experience of liftoff, for the sensation of weightlessness, and for the angelic, olympian views. Those not plagued by space-sickness will get “the experience of a lifetime” promised by the hype ads. As ticket prices moderate and demand increases it will become profitable to offer “enhanced” orbital vacations.

Exercise, sport, and even dance classes and events will exploit the opportunities of weightlessness. To make the most of the unparalleled views, there will be both “heads-up” view-plate display aids and experienced human guides to help sightseers identify and understand the geographical, geological, ecological and environmental, geoeconomic, and meteorological clues in the brilliantly sunlit panoramas below.

Picking out major and minor cities by their night lights will be a popular pastime. For astronomy buffs, the twinkle-free brilliance of the quickly shifting starscapes will bring a foretaste of heaven.

The leap from Earth Orbit tours to deep space excursions such as lunar swingbys is relatively easy. [MMM # 21 Dec. ‘88 pp 2-5 “Lunar Overflight Tours” available by SASE plus $1 to “LRS”] If part of the vehicles (and their outfitting) involved is “Made on Luna”, some of the revenues from this extension business will help boost the lunar economy. Better yet if the companies serving this trade are settler-owned.

Tours to the L4 and L5 Earth-Moon co-orbital fields, which may be the site of considerable construction and manufacturing activity and boast settlements of their own, will also become popular early extensions of LEO tour stays. From these twin vantage points, Earth and Moon can be seen together, 60° apart, and in similar phases (new, half, full, etc.). Excursions still further out may also be available.

As to “land excursions” on the Moon, in the early days when the preoccupation will be with building and establishing the first settlements and coaxing them toward some degree of self-sufficiency, it may not be possible to “visit” the Moon except on “working tours” as part of construction or prospecting crews, much as people now pay to go on archeological “digs”. Eventually, traditional “pampered tourist” type vacations will be introduced.

Such offerings will probably await the day when any and all new pressurized habitable space on the Moon is constructed of materials processed from the local regolith soils. Until then, the per square foot cost of habitat prefabricated on Earth will be much too high to squander on tourist activity for anyone other than the obscenely well-to-do.

For sightseeing surface excursions, pressurized cabins retired from Earth-Moon ferries and fitted with wheeled chassies and suitable motor units [“toads”, cf. MMM # 48 SEP ‘91 pp. 4-6 “Lunar Hostels: Part I: Amphibious Vehicles] should be available as sleep-on go-anywhere coaches. They might be brightly colored (“Tangerine Toads”?) for safe visi-bility in the overly gray setting, operated by a commercial distant cousin of Greyhound (Grayspan?).

As for touring Mars, that is an altogether different set of ifs. It is unlikely there will be any sort of tourist activity out that far until tested and proven second generation nuclear rockets are available that can significantly reduce travel times and total cosmic and solar radiation exposures. First to become available will be tours to Phobos and Deimos, Mars’ two close-in moonlets. These tours will feature extended observation of Mars from relatively high orbit (3,700 and 12,500 miles over the Martian surface, respectively).

However, much closer fleeting glimpses of the daylit side approaching and coming out of the aerobraking maneuver that ends the “cruise” out from Earth and puts the craft on a trajectory for either of the moons. Excursions to Mars surface itself may follow the lunar pattern, working tours first.

Is there a Lunar part in all this? Yes, to the extent that some of the vehicles, equipment, and provisions are lunar built, modifications of items first designed to bootstrap the unfolding of lunar settlement itself along with Earth-Moon trade. One thing builds upon the other — if we play our cards right, leveraging the most from every advantage. MMM

COSMOTIVE By Peter Kokh

Fuels Division

Most brainstormed Lunar Development Scenarios call for earliest possible **Oxygen** production. We need oxygen to make water, for atmosphere and biosphere, and as oxidizer for rocket fuel. The intent here is a) first to reduce the cost of return crew and cargo trips to orbit and back to Earth, and then b) to ship lunar oxygen to low Earth orbit cryogenic refueling depots to lower the cost of further Moonbound supply and resupply shipments from Earth, and finally c) to reduce the cost of expeditions to Mars and the asteroids.

While in water vapor, the combustion product of LOX and LH_2, there is an 8:1 mix by weight, the actual mix going in is a hydrogen enriched 6:1. So lunar oxygen cuts the cost of of 6/7th of the fuel mass. How can we do better?

An early and still often mentioned proposal is to use the hydrogen imported to the Moon to best advantage by first combining it with local silicon to make liquid **Silane** SiH_4 (a nominal analog of methane) and use that instead of hydrogen as fuel. While Silane is less potent than LH_2, its use promises to reduce the freight bill of sustaining the outpost or settlement by a significant enough percentage to be worth pursuing once the demand justifies the cost of required capital equipment. In the Silane family are other potential liquid fuels, some of which should work even better, such as Si_2H_8.

Are there other potential totally indigenous lunar fuel combinations? In theory, yes! Oxygen has a high enough affinity for Iron, Aluminum, Calcium, and Magnesium (all rather abundant in lunar soils) to make good fuel combinations — on paper. Most discussed are Iron, which exists in handy abundance as powdered fines, and Aluminum, which, alloyed with 25% Calcium, makes a very friable easily powdered alloy.

However, we have yet to engineer a [chemical] rocket engine that can use such fuels. It's not a matter of engineering difficulty so much as the fact of life that in none of NASA's scenarios is there more than token lunar development. Thus there is not enough perceived need to justify the expense of R&D on such fuel combinations and the motors to burn them.

Those of us interested in seeing tumble the "NASA Wall" that prevents opening the space frontier to the general public (as opposed to token elite proxies for voyeuristic gratification) need to find and/or encourage entrepreneurial development of such transportation modes. Even if cheap access to space (CATS) is realized in the Delta Clipper program, the cost of shipment of goods into and out of the lunar gravity well will remain higher than it needs to be without the development of refueling options using "all lunar" fuels.

Once all the fuel needed to refuel a rocket bound for the Moon in low Earth orbit is produced locally on the Moon, the settlement's net bill for shipping and freight costs for needed imports the rest of the way from LEO to the Moon becomes moot. Not only will it be cheaper to import, but the fuel overhead cost of exporting will fall, increasing whatever competitive advantages that might already exist.

Hold & Hull Division

As we've hinted, space pioneers ought not to rest content with diversification of production for export and with maximizing market opportunities. They can improve their competitive position by paying themselves for the freight bill of both imports and exports. Using lunar-sourced fuels at every opportunity is just one part of this effort. Locally supplying as much as possible of the containers and vehicles used in import and export shipments will boost savings even further on items already competitive, and may make the competitive difference for other items marginally short of being so.

The idea of a Lunar Frontier Aerospace Industry will elicit gaffs of laughter from many. But recall the MUS/cle paradigm for lunar industrialization that we've previously recommended.

[MMM # 18 SEP '88 pp. 3-4 "Lunar Industrial MUS/cle", and MMM # 65 MAY '93 pp. 7-8 "The Fast Road to Lunar Industrial MUS/cle and the Substitution Game"]. It is an "appropriate" lunar aerospace industry we are advocating.

Lunar industry should not concern itself with those complex, lightweight, and electronic ("cle") components which require a sophisticated industrial base to manufacture and which can be made on, and shipped from Earth relatively cheaply. Instead, frontier industrialists should concentrate on the more massive, unitary, and simple ("MUS") components. These are items that would otherwise cost a lot to import because of their aggregate weight, but which can easily enough be made in the settlement's startup industrial shops.

What is needed is a glass composites industry to start off production of tanks, body panels, spars and truss frame members, etc. Second generation industries using local iron, magnesium, titanium, and aluminum can expand the selection of aerospace products it is possible to fabricate locally.

We are talking about:

√ **fuel tank**s both for depots and on ship,
√ unpressurized **cargo holds**
√ pressurized **crew compartment hulls**
√ **aerobrake shields**
√ **truss frame members**, etc.
√ many other lesser parts that "all add up."

A Lunar aerospace manufacturer could make these components and then assemble them with imported "works" cartridges (e.g. electronics such as navigation, control, and communications consoles, engines etc.) and slip-in harnesses etc. to make complete ready-to-fly craft.

Going one step further, here is no reason why Lunar industry could not make drone **Lifting body hulls** so that exports to Earth's surface could fly nonstop from the Lunar surface aboard one way space craft the majority of whose mass was manufactured there. There is precedent aplenty for such divided manufacturing. Martin Marietta, for example, maker of the Titan rocket, only makes the rocket casings, and then mates them with engines and other components made by other firms like Rocketdyne.

And as for more sophisticated space hardware? Why couldn't lunar owned & operated **salvage companies** retrieve derelict satellites and other largely intact space hardware for rebuilding in lunar shops, and eventual reflight and reassignment?. Why accept preconceived limits? MMM

MMM # 91

MMM Dictionary Entry "Commercial Space"

"Commercial Space"

> **"any for-profit endeavor or enterprise that increases the amount, scope, feasibility, and/or sustainable economic viability of robotic and/or human presence in Earth orbit and beyond."**

One might get the idea from many space activists that commercial space means private launch companies and small satellite manufacturers - only! Even if this is qualified with an "at this stage of the game" this short list betrays a troubling lack of imagination, coming as it does, from people who say they want to live somewhere other than on Earth!

While it may be easier, and safer, to restrict one's ambitions to the "toy space" of microsats and small launchers, our goal is to create a self-sustaining human economy beyond

Earth's atmosphere. This clearly requires **commercial entry into man-rated rockets and habitat hardware.** This has already begun. The for-profit SpaceHab shuttle payload bay module is already a reality, but has faced a rocky road.

Early plans for commercial tourist modules were ill-fated because they depended either on paper study spacecraft, or upon the government owned shuttle. Any effort to piggyback commercial for-profit activity on profit-be-damned agency programs is at the mercy of political pressures and bureaucratic procedures — hardly a place to put dearly acquired capital.

Many put all their hopes on the X-33 program. But the dream of **Cheap Access** from NASA seems troublingly self-deceptive. Meanwhile, would-be commercial players stall.

We clearly need **commercial manned access** to space. Yet the very presence of the shuttle system works in a highly preemptive manner to prevent such access from materializing. What is needed is to tie in with **a commercial manned destination:** a commercial space station. With the adoption for the International Space Station Alpha of the high inclination orbit favored by the Russians, there has never been more reason than now for an alternative, a commercial station-depot in a low inclination orbit vastly superior as a staging and refueling place for deep space missions. Alpha would serve Moon and Mars missions at a severe handicap in comparison. There will also be need in orbit for more lab space at commercial disposal than ISSA can or will provide.

We also need to dust off the **"Space Cartage Act"** proposed many years ago whereby anything once in orbit and without its own motive power, could be moved to another space location or orbit only by a commercial vehicle.

Yet there is another kind of entrepreneurial activity which has the potential to accelerate the realization of an open space frontier. It is not at the mercy of bureaucratic, administrative, or congressional whim. Why not? Simply because it is a path that does not threaten powerful vested interests. We are talking about **"spin up" research & development**.

"Spin up" works like this. The entrepreneur considers the many and varied technologies that will someday be needed on the space frontier. Next he/she considers what profitable terrestrial applications there may be for each of these. There follows a business plan, and ultimately a for-profit terrestrial enterprise which has the happy effect of pre-developing and debugging and putting "on the shelf" a technology which will one day help open the frontier - sooner and at less cost.

MMM # 132

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

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

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

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

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

Poor Ore Mining Technologies

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

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

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

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

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

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

Novel Building Materials

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

Glass-glass composites have been proposed, and lab-researched, as a promising option for lunar settlement industry. But if we learned to produce a versatile array of glass composite building products and manufacturing stuffs, that could be an immense aid to the economies of countries that must presently import vast quantities of lumber and other products. There would seem to be ample economic incentive for taking this exotic stuff out of the labs, make fortunes in doing so right here on Earth, and in the process develop, debug, and put “on the shelf” a ready-to-go industrial technology that could be a backbone of early lunar and Martian industrial settlements. We developed this idea in more detail in MMM # 16, June 1988. But while glass fibers are finding their way into new concrete formulations, no one has bothered to try to earn a buck by taking glass composites themselves beyond the laboratory curiosity stage.

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

Synthetic Chemical Feedstocks

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

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

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

"Biospheric" Technologies

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

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

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

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

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

The **Gospel of "Spin-up"**

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

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

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

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

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

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

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

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

MMM # 147

Return to the Moon: What's in it for Earth?

By David Dunlop

For many Americans, including those in the in the science and aerospace technology community, "been there, done that" is the almost reflexive intellectual and emotional response, to those who mention much less openly advocate a return to the Moon initiative. This quick dismissal is also symptomatic of the general public apathy toward the space program and the only modest level of political support That NASA generates in Congress. The Apollo program is the political high water benchmark of faded glory days for NASA It is also a huge historical achievement by what is now termed the greatest generation, ranking up there with the winning of World War II , and the Manhattan project.

The Apollo Program Benchmark

The American public was largely indifferent to the two most recent US lunar missions, Clementine, a test of SDI sensor technology that happened to use the Moon in its first mission phases, and the Lunar Prospector which was the first and the least expensive of the Discovery Mission initiatives to fly. Yet these missions did fundamentally change the perception of the Moon. With the discovery of ice at the permanently shaded lunar polar craters the Moon is now perceived as a place much more capable of sustaining a human presence. This human presence can in theory be much less expensive to maintain by the use of local water-ice.

Elsewhere, I believe the Moon is perceived differently. Only the Americans have sent men to the Moon. The Russians didn't make it. No one else was even in the running in those cold war years. Yet today, the capability to send men to the Moon exists no where. The capability to do so still exists as as a benchmark of technological progress and of the strength of the national economy. In a psychological sense the rest of the world is still in a "catch-up" mode. The "Luna Club" is still an exclusive one with only the US, Russia (formerly Soviet Union", and Japan having successfully achieved Lunar missions.

Today, the Japanese and the ESA are planning lunar missions. The Japanese Planet-B will orbit the Moon and send two penetrators to the surface. NASDA talks of a long-range Japanese intention to develop a lunar colony in the 2020-2025 time frame. While the Japanese funding commitment to NASDA is not great only NASDA and large Japanese corporations are talking about lunar bases. The Japanese clearly see the Lunar benchmark as an important measure of technology achievement, a spur to technological excellence, and as part of the economic future of a vibrant and leading Japanese and world economy.

The ESA mission, SMART-1 is the first European counter part to NASA'S new millennium series. It will use an ion drive motor to push their package out of the Earth's gravity well and into a lunar orbit. It will finally qualify the ESA as a member of the "Luna Club."

Clean Energy For Sustainable Development

Other US initiatives have been proposed such as the Inter-Lune One initiative which was submitted as a Discovery Mission Proposal by the University of Wisconsin. This proposal with Harrison Schmidt as the Principal Investigator along with the Fusion Research Institute at UW Madison proposed a lunar lander which would have measured the helium-3 concentration in the lunar regolith. Commercial fusion reactor technology has been the"holy grail" for nuclear research for the last thirty years but has diminished support. The 'Green' forces have limited the appeal of this research initiative as have the lack of a short term pay-off. With an energy hungry world however this lunar derived Helium-#3 resource still is a potentially big part of a sustainable, clean, high tech and prosperous global economy. The broad international collaboration on fusion research is clear evidence that all the major technology players understand this.

The fusion initiative doesn't get much space in the headlines and has struggled in recent years from diminished funding. It also is a benchmark of scientific capability and would not only be the engine of "clean and sustainable" economic growth for the world but it would also be the breakout technology for human expansion in the solar system. Fusion reactors would provide the means to make "short" transit times to Mars and the Asteroid belt a matter of months rather than years. Even long journeys to the outer solar system could be feasible with fusion technology as the enabling technology.

Engineering Development as Aerospace Corporate Welfare

In the absence of a cold war, the retreat from basic research, and the ascendancy of "bottom line" political rhetoric, the NASA space program might evaporate, and the same disease affects ESA and NASDA. There just isn't the political horse power of the Apollo and cold war era to fuel further development. The costs of investment are so large and the risks of failure are so great that private capital cannot be attracted for a "reasonable short term prospect of profit. Thank God for corporate welfare. The NASA, ESA and NASDA enterprises and their corporate dependents are the best bet for continuing development. Under the umbrella of the International Space Station work will continue.

The completion of the ISS will force a crisis for these enterprises. They could face a great scaling back unless they come up with "the next big thing" for self perpetuation.

A return to the Moon for developing a Lunar Base would provide such a ticket. It is important to learn whether Lunar gravity is sufficient to maintain cardiovascular function and whether Lunar micro-gravity is adequate for the rest of the biosphere on which we humans depend. It will maintain an inter-national scientific collaboration which permits the addition of national partners such as China, India, and Brazil in this very expensive enterprise.

A Return to the Moon will necessitate several Engineering Developmental Challenges:

1. A truly cheap reusable system providing manned access to LEO is needed. Now that the single stage to orbit approach has been abandoned by NASA for the moment, a two stage approach to LEO as now seems necessary will be a immediate goal.
2. A cheap heavy lift capacity to LEO is needed and a high production volume big dumb reusable booster is needed. Several such vehicles were proposed in the 60's which would still be providing much less expensive costs per pound to orbit today with an expend-able design. A reusable design might not mean reusable in the sense of returning to Earth but in the sense of creating large habitable volume in orbit for fuel storage or atmospheric gases, habitable volume, or merely enclosed vacuum volume for safe EVA assembly work on repair of satellites. or solar array subassemblies. Such dual use considerations of large dumb volume would of course mean a heavier tank structure, but there is no free lunch.

The potential use of the shuttle external tank has been studied and the creation of "new land" in the ocean of space with each launch should not be missed. This cost will of course will not be cheap but each such tank should be first designed for reuse in the future and should be outfitted with a solar array driven, electrodynamic tether fuel-less propulsion system as is now being developed for flight testing. This enhancement of large booster will make them more expensive but will also permit them to be stored in orbit for future use. The flight test of this fuel-less propulsion system in the next two to three years will tell how effective such a system could be in now only station keeping for large mass structures but how high a storage orbit can be attained.

The creation of an annually small but growing inventory of large dumb volume environments could reduce the subsequent costs of many future projects:

- Creating new volume on the ISS
- Providing fuel and storage capacity as a back-up to the ISS in case of catastrophic losses in a meteorite storm
- Providing fuel and atmospheric tankage capacity on the lunar surface for a lunar base.
- Providing fuel and atmospheric tankage capacity and human habitation capacity in GEO for a human tended construction station for a solar power satellite
- Providing fuel and atmospheric tankage and habitation capacity for an L5 outpost for the development of an O'Neill colonies.
- Providing a standard structural component for a large rotating space station such as originally envisioned by Von Braun.
- Providing fuel and atmospheric tankage capacity for a Mars space station. We might consider sending a space station into Mars orbit in support of a Humans to Mars program. with the capacity to support and provide a back-up environment in close proximity to the surface as an additional fail-safe system to the Mars Direct strategy.

I'm sure this list of potential future uses of large dumb volume could be expanded. All this to underscore that a tank in orbit is a terrible thing to waste. All this to underscore that a commodities market for such tankage should exist for those willing to provide the incremental cost of designing for such utilization and paying for the cost of the fuel-less propulsion systems needed to get them to a high safe storage orbit. As the reader may have noticed the frequency of their use for storing fuel and atmospheric gases is the least cost and most likely best use of these tanks. Retrofitting these tanks in orbit would be cost prohibitive for many purposes. Large dumb volume capacity should be extensively needed as a human space-faring civilization expands. It is only very short term bottomline thinking that makes this proposal "infeasible." Storage and reuse of this capacity would greatly lower the cost of many subsequent projects and therefore should be studied as a "futures infrastructures commodity."

3. An orbital transfer vehicle is also needed to expand and tend GEO platforms and provide a supply chain to the Moon (and later to Mars).
4. The further development of TransHab will provide next generation modules for extending the life of ISS, providing capacity for space tourism, and making a modular system for Lunar Base development, and a future Mars Base.
5. The just canceled funding for the Lunar/Mars base mockup initiative at JSC will need to be restored so the CELSS will be mature by the time it is needed.
6. The development of mag-lev launch rail launch systems for high frequency low mass payloads to orbit is needed.
7. An orbital debris mitigation program should be initiated to limit and decrease the hazards of “space junk” to expanded levels of manned activity.
8. An international rescue-crew return vehicle capability or mini-shuttle. Recent new of German interest in developing this option will provide a manned vehicle for ESA.
9. Rather than scaling back aerospace corporate welfare in the G-8 nations these challenges can maintain employment, stimulate engineering education, and rekindle the Apollo vision in the next generation. These pieces of infrastructure not only provide the support for a Lunar Base initiative but also pave the way to a serious contemplation of Mars.

The Political Economies of a Lunar Initiative Partnership

The number and scale of these investments also provide plenty of “room’ for spreading the work among the international space faring nations. Getting the political commitment to undertake new engineering objectives as the global economy develops is still going to be difficult. It is reasonable to expect more national economies developing to the point where they have the capacity economically and politically to support aerospace industry initiatives which lead to space faring partnerships. The development of cheap access to space should greatly lower the cost of participation by nations that are now in the second and third economic tier. Nations with maturing industrial and academic capacity will see the educational stimulus of such participation and also see participation as an important national political asset for national pride and as a benchmark of economic progress.

The best arguments for this view of the political economies of third world countries are:

a. The stubborn refusal of Russian to retreat from their spacefaring capacity even though as present their economy can’t “rationally” support the “luxury” of a space program. Could military requirements and defense of national sovereignty be worth it?

b. The persistent and long term commitment of the Chinese to develop and refine their missile program and now a manned capacity.

c. The persistent and successful efforts of India to expand its booster capacity to GEO capacity.

d. The growing capacity of Brazil in aerospace and the development of its own equatorial launch site.

Like the International Space Station, the effort to ramp up to a lunar base project will be a complex political as well as technological partner-ship. Part of the glue that has held the ISS together has been the international perception of disgrace due to the unreliability of any member withdrawing from the project or not honoring its commitments. It clearly has not been easy for the Russians to continue but they have. When the ISS has become unpopular with the US Congress due to perennial cost overruns the issue of honoring international commitments has carried weight. Japan’s stagnant economy while limi-ting new plans has not detoured their commitment to the ISS.

Another art of the glue that drives this partnership is the sense that the national partners cannot permit themselves to fall behind others in technology capability.Just as the emerging economies feel a need to catch-up there is the resentment of allowing one country to develop a commanding lead. The US is continually poised on the razor edge of the competitor/ partner position as the remaining superpower. It must itself not fall behind or face the treat of losing its leadership position. Selling the Moon Base to domestic political constituencies on its own scientific merits may not create a ground swell of domestic political support among the current Space Station partners but the persistence of entrenched bureaucracies to press for this commitment to their own perpetuation is not unrealistic.

Commercialization

While a Lunar base is sufficiently high risk and of a scale beyond what private capital will now risk, the enterprise will create many smaller opportunities for commercialization. The recent announcement of a withdrawal of the US from some ISS commitments is an example that has resulted in the Italians stepping up to fill the gap of a needed habitation module. Their multi-purpose logistics module design will be upgraded to provide a habitation module. This lets a new initiative emerge.

The development of an orbital transfer vehicle that can provide the boost to the top of Earth's gravity well can also provide a more robust way of reaching GEO. The GEO communication satellites of today are surely destined to become enhanced communications platforms with huge solar power arrays and more powerful signals. GEO antenna farms will be developed by telerobotic technology which will permit the delivery, installation and removal of telecommunications equipment. The exploding demand for phone and data communications will mean a continually expanding market for such communications platforms capacity. The saturation of GEO orbital slots will require the upgrading of the capacity of existing slots. It is therefore probable that an orbital transfer vehicle and telerobotic system capable of creating and servicing the GEO platforms will result. Since the high value of the GEO antenna farms has a well established market, it seems a reasonable bet that a commercial development of this technology will result. It remains to be seen, however, whether this will occur with a limited government partnership or without a major government subsidy. The potential for a commercial orbital transfer vehicle being developed may not be far off.

The deployment of telerobotic arms systems on the ISS which will participate in the further construction process is the beginning demonstration of systems that could be used for next step projects such as an expanded GEO broadcast satellite platform, a prototype solar power satellite, or orbital retrieval vehicle which could retrieve dead satellites.

Commercialization of niche markets which have a prospect of growth and stability of utilization is likely to be a force in the creation of some of the missing pieces of a return to the Moon.

Summary

The Return to the Moon offers many benefits to the Earth including education, corporate welfare employment of high technology industry capabilities, the maintenance of international partnerships, hope for a clean energy future, and support for expanded telecommunications capabilities. These benefits will still be propelled by government funding as the predominant mode in the next 20 years, but with expanding private funding where growth in demand for commercial services is foreseen to be consistent and relatively low risk.

The return to the Moon is f credible in providing these benefits. The "been there and done that" reaction of many would suggest that the rationale above is not understood. It think the arguments above will prevail when at the end of the ISS construction we come closer to determining "the next big thing." <DAD>

MMM # 179

Trash >> Treasure = Trashure
Waste >> Resource = Wasource

‘Trashure’ Creativity & ‘Wasourcefulnes’:
Two Critical Talents on the Space Frontier

By Peter Kokh

A shining example

There are many people who make their living, and many more who supplement what they can buy from day job wages or salaries by rescuing things others have thrown out as trash. They/we (for I am surely one of the later) reuse some things as they are, refinish other things, and find wholly new uses or adaptations for still other items. The practice of turning Trash into Treasure (“One man’s trash is
another’s treasure” has so long been a part of our culture that the hybrid word “trashure” is now well
established as a search engine exercise will demonstrate.

Yet it is certainly the case that most people are not up to speed on this -- perhaps they lack the spirit of creative adventure involved in “dumpster diving” and the thrill of acquiring, for little effort or money, something to treasure in their homes, or perhaps they can’t be bothered to make the effort, or perhaps they disdain anything with a “history” or perhaps they have the cash to buy “new” (read unsullied.)
Yet trashure is well-enough established to have become a respectable, even admired hobby.

On the Lunar and Martian frontiers, as on Earth, pioneer artists and craftsmen will find used materials and items their least expensive and most readily available option. It will pay for settlement citizens, individual and corporate, to presort discarded items and send them to a Stuffs or Trashure Market where, hopefully, a good and growing percentage of it will be adopted for reuse, rehabilitation,
or transformation into new utilitarian and/or decorative items. “Dumpster Diving,” “alley scrounging,” and
“moving day curbside scavenging” will come out of the closet.

Creative and enterprising volunteers will turn this windfall into unique furniture and furnishings items, works of art (sculptures, for example), musical instruments, toys, and even personal adornment jewelry items -- for personal use and for sale. The trashure industry will grow as the amount and variety of discard items increases, becoming a significant complimentary sector in the overall economy.

Everyone will benefit, as this activity will significantly expand the variety of locally produced items. Visiting trash stuff markets, flea markets, arts & crafts fairs, and specialty shops filled with born-again items on consignment will add weekend pleasures to spare time menu options.

Front End Trash Reduction Measures

Not all pioneers will have the creative talent and urge to make use of the flow of trash. If the volume of discarded items and materials is not to swamp them, up front measures will be needed to reduce the sheer amount of stuff finding its way to the general pile. Here are some simple measures that will help (that some of our spoiled manufacturers may be temporarily inconvenienced by having to switch philosophies and gears should not dissuade settlement fathers from insisting on these protocols.)

Using KD (easy “knockdown” or disassembly-friendly) methods of assembly, especially when dissimilar materials best recycled separately are involved. We are used to dissimilar items being permanently “bonded” by adhesives, and thus mutually contaminating one another as far as
economical recycling options are concerned. a tax break on items so manufactured, calculated by
special rates for kind of material and strategic value. a turn-in credit reward for consumers and manufacturers (who may discard unworkable seconds) discarding items in a properly sorted and disassembled state University involvement through a department of Industrial Engineering, in

searching for designs that make secondary adaptive reuse relatively simple. Containers that can be reused as canisters, as stackable dresser drawers, as planters, etc.: [The "world bottle" was an inconclusive project in the 1970s to design a beverage bottle that could be used as a building brick.] If there are sufficient incentives, manufacturers will be motivated by profit to create items, normally for one-time use, that
can become "pop" stuffs for all sorts of uses. We'll revisit this idea in a future article.

The same strictures should apply to the construction industry. Methods that make separation of materials that need to be recycled separately (i.e. metals and organics) all but impossible such as adhesives (yes, Liquid Nails) and staples, should be taxed sufficiently to provide the money (and labor) necessary to undo these difficult bonds, especially when organic or synthetic materials that embody elements scarce on the Moon (hydrogen, carbon, nitrogen, but also some metals such as copper, brass, zinc, lead, gold, silver, platinum.) KD! KD! KD! The tax should be sufficiently onerous to make KD assembly methods more attractive. Think of those who follow, if what you build or put together is not meant to work or perform forever!

Extending the paradigm: packaging waste

In MMM #4, April 1987, "Paper Chase II" (www.asi.org/adb/06/09/03/02/004/paperchase2.html)
we speculated about ways settlers could do without paper.Paper as an agricultural byproduct should be reserved for quick-turnaround uses: art du jour or temporary children's art, for example, where it can easily and routinely be recycled back into the biosphere-biomass cycle. On Mars, where the stuffs of organic compounds (hydrogen, carbon, and nitrogen) are comparatively abundant, such stringent restrictions may not be necessary (but still wise!)

Paper and cardboard and other packaging materials constitute one third of the total volume of trash and rubbish in modern America. On the Moon, packaging will preferably be made of inorganic materials (e.g. wire mesh bags and baskets, foil, "tin" containers, etc.) or will be formulated and/or designed for easy craft reuse, especially as media for developing artistic talents in children.

There are many other suggestions in the article mentioned. The packaging nightmare has been greatly exacerbated in recent times by having to resort to shrinkwrap cardboard packaging for small items previously held in open bins, as a shoplifting counter-measure. Hopefully, the settlers will come up with other means of discouraging shoplifting in order to do away with this wasteful use of paper and plastic based materials -- but something short of Plastics.

Plastics

Most of our plastics are coal- or petroleum-derived. But there has been considerable effort in the past few decades since the first Oil Crisis, to derive suitable organic feedstocks from "oliferous" plants. Those who would pioneer the Martian Frontier are looking for even more direct routes, synthesizing basic plastics feedstocks like ethylene and propylene directly from the carbon, oxygen, nitrogen, and hydrogen in the Martian atmosphere. Their success will be of use to Lunan pioneers as well, though without such an
atmospheric reservoir of needed key elements. Import shipment "dunnage," the "co-imported" shipping container stuffs such as barrels, crates, skids, separators, dividers, and cushioning materials, will be a
primary source of simpler plastics such as polyethylene and polypropylene that can be reformed and reused over and over again, if separately recycled. Current plastics recycling is mostly limited to those containers marked 1 or 2 (inside the recycling triangle symbol). Other containers may be marked properly, but the market for their reuse is not strong enough to support active recycling.

On the frontier, it will be the best strategy to allow in (by import) only those plastics the settle-ment is prepared to recycle. Subvarieties, color-coded both for proper sortation and for use in creating KD children's toys, could help expand options. We have written previously about Plastics in MMM #26 June 1989, "Toy Chest" and "Thermoplastics" pp 5-6. These articles will be republished in MMM Classics 3, as a free access pdf file, in January, 2005. Also relevant is the article “Stowaway Imports” in MMM #65, May 1993.

Mining Wastes & Byproducts

Mining wastes include tailings, piles of gravel and other solids leftover after the extraction of the sought for element or ore out of the host soil or rock material. Also a problem is unrecycled reagents or acidic leachings dumped into ground water or drainage basins. On Earth, we can try to handle such problems by fines, but a far more effective way is to promote the identification, with University assistance,
of profitable products that can be made of such unwanted materials and wastes, and/or profitable markets for sale of such byproducts as is. It can be more profitable to sell byproducts than to discard them. But product and market development must be aggressively pursued.

This kind of thinking and these kinds of processes need to be incorporated in the drawing board stage of development of lunar industries and their diversification. New products from what would otherwise be wasted will mean a more diversified supply of products for domestic use on the Moon, but also a more diversified portfolio of products for export to other in-space markets. Making use of tailings, used reagents and leachings is best seen as a great opportunity for Lunar enterprise, rather than aburden that erodes their profit margins. Those without the right attitude should be discouraged from getting involved.

Tailings will be the host regolith minus the extracted element or suite of extracted elements. The flip side of the coin is that tailings are now “enriched” in all the elements not extracted! That makes tailings a potential feedstock for other materials.

Tailings that are of no further economic use, can perhaps be reused as aggregate for lunar concrete, paving material for lunar roads, and sintered into building materials for unpressurized vacuum exposed structures such as shade walls and radiation-shielding canopies or ramadas for
storage purposes.

The tightest possible recovery and recycling of organic reagents and acid and heavy metal leachings will be a cornerstone of lunar industrialization. Given the tight supply of hydrogen, carbon, and nitrogen, and the need to reserve as much of that as possible to support the maintenance and growth of lunar settlement biospheres, no other policy makes sense, either environmentally or economically.

Manufacturing Wastes & Byproducts

Manufacturers will operate under the same environmental and economic common sense constraints. Material left over from exuding, casting, or machining parts will have to be recycled back into the source bin. Material contaminated by machine oils can be cleaned in house or shipped out to a service provider. Shipping containers that cannot be reused, will either be turned into sideline products or sold on a web-based byproducts and waste materials market. Most of these materials will be reused domestically on the Moon. But some may find viable export markets, further improving the Moon’s import-export
equation and overall economic viability.

Consultants will suggest new uses for manufacturing byproducts and waste materials will become a key player in making the lunar industrial system work well. Some of them may even take over a customer-approved plan as prime contractors. Bigger manufacturers may have in-house research departments doing this, spinning off subsidiary enterprises in the process. Waste reduction andrecycling will be good business.

Agricultural “Wastes”

Once I was told by an expert in space agriculture that cotton was not a candidate plant for lunar agriculture. Despite the fact that no other fabric is as versatile, comfortable and recyclable, there is too much waste biomass involved. Fully 86% of the plant by weight is of no use. The statement, expert source or not, is absurd. One has only to look at the example of the African-American agricultural pioneer, George Washington Carver, with well over a hundred patents to his name on products that could be produced from the peanut plant. What Carver did in Tuskegee, Alabama should be a challenge to would be lunar farmers and farm product processors. That example could inspire a considerable diversification of lunar agriculture-based industries and enterprises. But even should futureLunan processors have less luck with cotton, it remains true that biodigesters have been demonstrated that can take any and all waste biomass and reduce it to an edible tofu like product, with only 2% stubborn waste.

Liquid and Liquefied Wastes:

A Plumber's point of view As a jack of all home-improvement trades, plumbing among them, I believe a lot of problems and challenges can be minimized by proper plumbing. In MMM #40 NOV '90,

"Cloacal vs. Tritreme Plumbing" I described our present municipal plumbing systems, descended without substantial improvement from that of the ancient Indus Valley town of Mohenjo-Daro c. 2,500 B.C., as "cloacal." A cloaca is the discharge system used by monotremes (one hole), primitive

mammals such as the duck billed platypus, in which the anus doubles as ureter. "One hole serves all." "One drain serves all." Nowadays some cities are belatedly trying to separate storm sewers from sanitary sewers. Too little, too late.

On the Moon, where we have a unique opportunity to design our infrastructure from scratch on a clean drawing board, we can institute polytreme, multi-hole multi-drain systems to minimize the treatment and recycling challenge. Agricultural runnoff, shower and sink runnoff, toiled wastes, manufacturing waste water - these can all be plumbed separately, minimizing the problem instead of compounding it. If we start off on the right foot right away, this way of doing "business" will not be seen as a burden, but

as the only civilized way of doing things, implying derision of Primary Point-Source Treatment

Rigorously separated polytreme drain and sewer plumbing systems will make the job of finding market-worthy products derived from properly separated wastes that much easier. And even this challenge will be minimized by primary Point-Source Treatment. Biological gray water treatment of human wastes, more on the model of the 20 year plus field-tested Wolverton Graywater System

(http://www.wolvertonenvironmental.com/ww.htm) which provides the home, office, restaurant or other toilethosting, modules or structures with fresh sweet air (regenerating oxygen from carbon dioxide), abundant greenery, and sunlight than on the workable but laboratory-like GreenHab system installed at the Mars DesertResearch Station in Utah. Such systems will enable synchronized modular growth of settlement biospheres because every new toilet-equipped unit, residence, office, commercial, industrial, or other, will be equipped to execute a 95% pretreatment of human wastes before the gray water enters the settlement municipal sanitary drain system. The central burden for both water and air recycling will be

enormously minimized. Waste waters from other sources can also receive primary treatment at the point source, again enabling the modular growth of the biosphere, with farming and industrial areas each contributing their share.Where does this put us?

Trash and rubbish are one thing. liquid wastes and sludges are something else, carrying the connotation of unclean and unsanitary, of polluted or even toxic. My point? If on Earth we can afford not to extend the same rehabilitation effort to liquified waste as we do, with growing frequency, to trash, that will not be the case on the Moon.

On Mars, the pioneers could probably get away with indulging the same bad habits we have on Earth. The difference can be summed up in one word: volatiles. Most wastes, especially liquid ones (with or without solids) are composed of organics; volatile elements abundant on Earth, and accessible on Mars. On the Moon, these elements must be scavenged from solar wind gases trapped in the upper

regolith layer or refined from comet-derived polar permashade ice deposits. What on Earth is useless and without value will be priceless on the Moon.

Toilet systems that use human wastes to feed plants are now demonstrated. Entrepreneurs have learned to use drained motor oil as fuel for heating. But most organic

wastes are just “wasted.” The Lunan pioneers will need a whole new attitude towards all kinds of organic wastes from human wastes, to food production and preparation wastes to chemical plant wastes. They will need to do the mental flip flop that equates waste with potential resource. Waste not, want not! It’s not just for the dinner table anymore. This
kind of frugality is an investment in the future

To promote the idea, first among potential Lunan pioneers, then among our terrestrial brothers and sisters, we offer the trashure-parallel coinage: waste + resource = wasource pronounced “WAYsource”.

Wasources must be integrated into the Lunar Resources pantry. Wasourcefulness must become part of their frontier culture, an aspect of settler resourcefulness. The frontier government can offer incentives to entrepreneurs and established companies alike to develop nontrivial uses for various types of waste. An Internet-based waste meta-inventory database and exchange program could be inaugurated. A frontier university should be very much involved both in maintaining the system, in expanding the categories as needed, in research and development of new processes and product lines, and in waysource-based enterprise creation and assistance.

Wasources represent invested hydrocarbons and other organic and synthetic enabling elements. Chemical feedstocks for plastics, lubricants, even pharmaceuticals are among the rewards. The volatiles involved will either have been brought from Earth as food stuffs, agricultural nutrients and fertilizers, medications, chemical reagents.

Some will come from routine gas scavenging of the solar wind gases in the regolith. Much of this will find their way through the human digestive track. Some of it will be waste byproduct of various food and regolith processing and manufacturing orations. The salient point is that any volatiles embodied in wastes (of whatever kind) should be treated as an investment, an endowment that should continue to produce income - not be flushed into some never-never land out-of-sight-out-of mind from which retrieval may be difficult and unprofitable.

Storing wasources

In designing a complete and efficiently organized storage system, thought must be given to storing waste liquid and sludges, carefully segregated according to source and gross chemical makeup. At least that should be a goal for priority implementation.

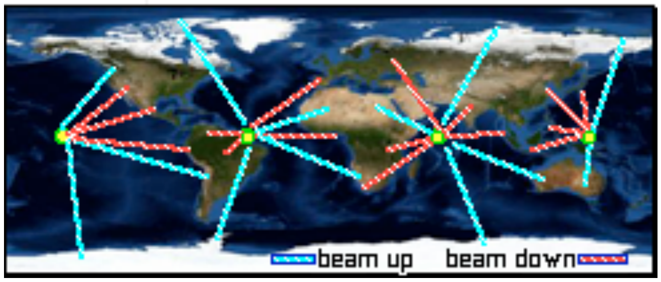
Before we get too far along in developing our initial beachhead outpost into an infant settlement, we will either be already recycling human wastes, hopefully near their individual point sources as in the Wolverton toilet=plant bed system, or we will have chosen by default for the settlement to fail. But early on, before such systems are in place, we will want to store these wastes in durable containers from which they can be retrieved when we are ready for them. To do that, all we need is to put them in permanently shaded areas (under a shed will do) where their chemical wealth can stay frozen and inert. To do otherwise
= would be seen in retrospect as an act of treason against the future human frontier, much as the currently accepted practice of scuttling the shuttle external tank just short of orbit is likely to be so judged, if only for its seven tons of copper, each, of almost astronomical value on the copper deficient Moon.

Pioneering the Moon will take a whole new set of attitudes, if we are going to make it work to enhance the viability of human outposts on a hostile world.. Wasourcefulness is one of them. Fortunately, there is a subculture paradigm for inspiration: that of “trashure.” < MMM >

MMM # 210

The WorldWide Orbital Grid Proposal
WWOG - World Wide Orbital Grid

Space-Based Solar Power: Another Route



By Peter Kokh

Ground-Based Solar helps, but can never be enough

Space-Based Solar Power, or Solar Power Satellites combine two technologies: solar collection in space, and power beaming. The advantages of collecting solar energy in space are clear to anyone who has looked at the numbers. Yes, we do also need to greatly multiply the use of ground-based photovoltaic and other solar energy collection systems. But we would have to quite literally pave over the state of Arizona and much of neighboring states with solar panels to supply the national power demands, and the real estate costs of that could be higher than the up front costs of space-based systems.

Yes, we need to continue to make homes and all other structures more reliant on a combination of energy-saving construction methods and architectures, and on site energy generation. The more individual home and building owners do their part, the better. But a plan that counts on widespread support by individuals facing their own microeconomic facts-of-life is not a plan at all for a national, let alone a global, approach to replacing dirty energy generation systems with clean ones.

The Long Lead Time Hurdle

The problem with space-based power generation schemes, however, is that as much sense as they make, they will decades to put in place. That long lead time may be enough to discourage many and send them looking for second best options that can be put in operation in shorter time spans. It would be tragic if the Space Based Power strategy that the National Space Security Office called for on October 10th, is not pursued because supporters want all the plan, when in fact there is a nearer term option that could be very attractive, cost far less, and yet guarantee that the full plan be eventually realized.

Divide and Conquer!

We suggest that we concentrate on the most basic half of the plan: power beaming, not just from space, but to space. This would require rectennas in both orbit and on the ground. It would require considerably less tonnage of material for construction, a threshold that could be met by launching all the components from the Earth's surface. Why?

Detractors of Space Based Power Generation Systems number not only Mars advocates who disingenuously want to dismiss and discredit anything that may legitimize a return to the Moon and lunar industrialization, but vested interests in terrestrial power generation systems: coal, oil, gas, even ethanol. But this same unholy alliance would be all in favor of the establishment of a single world wide power grid, where excess power from anywhere could be beamed to space and relayed to wherever it was needed.

In other words, let's concentrate on the creation of a space-based world power grid first of all. Oil people, tar sands people, coal people, hydroelectric people -- they will all see the sense of that. The effect would be to stabilize the world economies and greatly level the economic playing field, benefiting developed and developing nations alike.

At the same time, we will have put into place an orbital power relay system, that when the shortages that come from uneven distribution of fossil fuels and other fuels can no longer be managed by shifting loads because the total amount of terrestrial power generation is now insufficient, you just need to add solar arrays to these orbital relay stations to tap a bottomless supply of clean power. That the orbital worldwide power grid is in place will easily derail any further opposition to "out-sourcing" additional power generation to off-surface locations, made economically feasible by the use of lunar materials.

Wireless Power Transmission has been Demonstrated

On June 5, 1975, NASA successfully beamed 34,000 watts (34 kw) of power from the Goldstone Dish over 1.5 kilometers (0.9 miles) to a JPL-built rectenna on the Goldstone collimator tower on a nearby ridge -- at more than 82% efficiency! Watch this 2 minute Video:

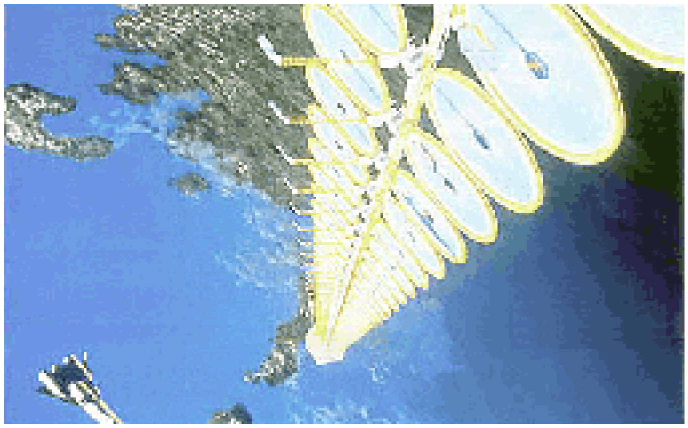
www.youtube.com/watch?v=jd47JXuz0g8

The WWOG could help now, in the interim, not only by shifting excess power, but by connecting to unused power sources.

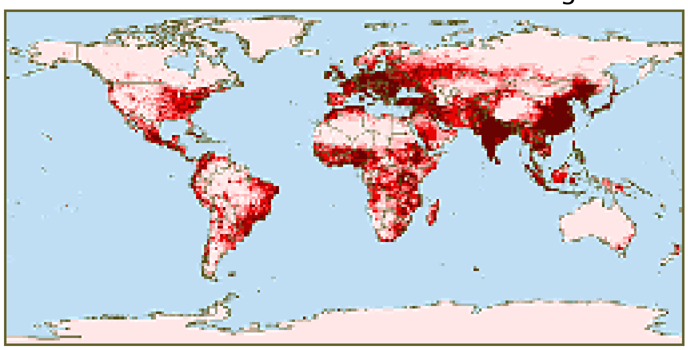
It is our belief that since it does not require components made on the Moon, a World Wide Orbital Grid could be put in place in less than half the time needed for realization of Space Based Solar Power systems, without detouring or delaying the latter. Quite to the contrary, this phased approach would speed up full realization of the SBSP plan by effectively disabling opposition by the powerful vested interests of Coal, Gas, and Oil producers. Here is how WWOG would help:

- shift power loads globally rather than on the present subcontinental basis, with much greater flexibility of sourcing. Excess power from Hydro-Québec could be beamed to India as easily as to Arizona instead of just to the US northeast.
- Regions with chronic power shortages and no nearby sources of surplus power would find quick relief.
- Areas with fossil fuel reserves, instead of shipping those fuels (before or after refining) could derive added sales value by generating needed electrical power and exporting that by the WWOG instead of via pipelines and tankers which have environmental risks.
- Areas with little domestic power need but great capa-city to produce power would now have a major export market to catapult the local economy into the new integrated world grid. Four examples:
- Underpopulated Desert areas without fossil fuel reserves but with abundant sunshine/ wind.
- Antarctica: wind farms emplaced along it's 360° circling coast could beam power to power-hungry areas, without negatively impacting the Antarctic environment. Antarctica has the world's strongest, steadiest winds constantly blowing in the same direction, northward, away from the south pole. This power source is now untapped.
- There may be similar steady winds buffeting the arctic coasts of Alaska, Canada, Greenland, Scandinavia, and Russia-Siberia
- OTEC (Ocean Thermal Electric Conversion) units anchored off the US eastern seaboard in the Gulf Stream could supply abundant power to wherever needed. The Japan Current could be tapped also.

In short, not only would the WWOG even out power distribution globally, and with it level the economic playing ground, but it would tap considerable energy sources not now in play. This would help ease us through the period of two or more decades before a Space Based Solar Power Grid could be put in place, piggybacking on the already established WWOG. It is a win-win situation.



An orbiting solar array design currently highly favored. How well a proposed design lends itself to construction with lunar materials should be the deciding factor.



Global Population Density Map. With a World Wide Orbital Grid, power generated in unpopulated areas, including arctic regions, could be beamed anywhere.

Phasing in Space Based Solar Power with a WWOG

- If we can't have our cake with frosting, let's push the cake by itself. In time the frosting will be added. The alternative is that we get nothing, the world sinking into energy wars and general disorder and chaos.
- The WWOG builds on existing power generation systems, their present location, the needs of under-developed and developing areas, meshes well with world economics, will have the full support of power generation companies, and will create a new level (double entendre) of international cooperation.
- That's a plan that doesn't have to wait decades before results start justifying expenses.

How do we start?

There are several unanswered questions about power beaming through the atmosphere and to and from space. These questions concern efficiency and best choice of wavelength. safety for humans, wildlife, vegetation, and livestock. We need a step by step plan to investigate these uncertainties and zero in on the best options.

Then we build an orbiting rectenna and power beaming relay demonstrator, and if it passes muster, put it in operation in an area of that includes regular power need/supply inequities, both deficiencies and surpluses. Then we ramp up to mass production of these units and their deployment to create the WorldWide Orbital Grid.

Getting Everyone to "Buy In"

Along the way, we create a consortium of power generation companies and grid managers who want to be involved. Pair them up with developed and developing nations that see the WWOG as in their best interests and establish **a WWOG Authority** representing all these players and interests.

Finding investors is crucial. The members of the WWOGA (individual power generation companies) can place surcharges on their terrestrial power customers to help support expansion of the WWOG. Power generation companies with unsold excess capacity should be quick to invest as a way to maximize their profits and grow their power generation capacity.

No part of the inhabited or uninhabited world (not even the deep Arctic and deep Antarctic, from where orbiting relays may at times be too close to the horizon for effectve beaming) will be too remote to benefit. Power will be available not just to cities and manufacturing complexes but to agricultural and other areas: for irrigation and seawater desalinization, etc. Teleoperated nuclear plants could be established on remote uninhabited islands, to contribute to the grid. In general, establishment of a WWOG will lay economic grounds for would peace and prosperity. widespread economic well-being,

Of course, it does not stop dirty power generation or start regreening the Earth, but by laying the natural foundations for SBSP while disarming all opposition, it will bring the day of a prosperous cleaner and greener Earth that much closer, as well as make more inevitable the establishment of an Earth-Moon economy.

Meanwhile ...

There is much we can do in America and else-where to slow the growth of dependence on fossil fuels for power generation. We can do much more in the way of on site solar power generation for home and building use -- and not just in the sunny southwest!

"When you look at solar usage, the US is currently third behind Germany and Japan. Both of these countries currently have the solar footprint of Northern Michigan, but they are both able to make solar power work for them." - www.altenergystocks.com/ archives/2005/10/

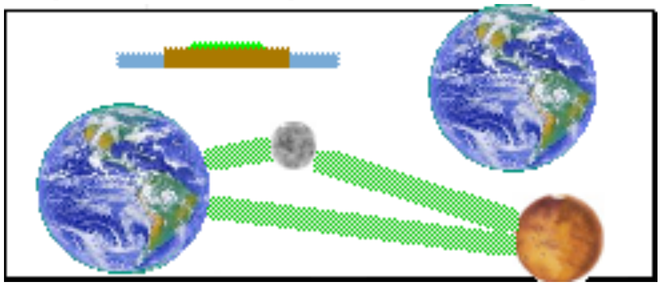
By doing as much as we can with ground-based solar, we will not only be buying precious time, but we will be easing the public mentality towards a wold view in which solar energy is King. That will help weaken the influence of the Vested Interest coalition of oil, gas, coal.

Action Item

I will be presenting these ideas to the National Space Society Space-Based Solar Power committee for consideration. Dismissing this phased in approach in favor of going for the whole plan or nothing, involves the higher risk of failure. We need to avoid swimming upstream when there is this sure fire phased in plan that all interests involved will accept much more readily. And, though it is not much mentioned, a Space Based Solar Power system that does not aim at a World Wide Power Grid will only exacerbate the divisions in the world which motivate unrest, conflict, and war as well as unacceptable inequities. We are all in this together. There is no "American" solution, only a world wide one. **<pk/MMM>**

MMM # 211

"As the World Expands" The Epic of Human Expansion Continues



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.moonsociety.org/publications/paper/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 sportscasts 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 Theilhard de Chardin (died 1955) has become reality.

Humans: 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 intercommunicating 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 extend 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.

With 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.”

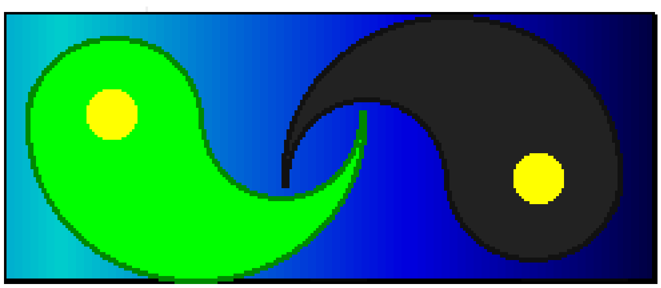
Both travel and communication will take longer to other points in the solar system, but are of little consequence in comparison to the difficulty of travel and communication in the post-Columbus, post-Magellan world. To continue to think of “world” as confined to Earth, is to think in tribal terms.

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**>

MMM # 214

“ Mother Earth & Father Sky ”



The “Planet Earth & Space” Conference Proposal

From Peter Kokh, Moon Society President
Member, NSS Board of Advisors

An Opportunity April 2008

Last December, Board member, Dr. Schubert first identified an opportunity for us to apply for EPA funds for a “broad-based” conference on "Climate Change" remediation measures, and, with enthusiastic NSS support and engagement, and input from a handful of others, we put together a specific proposal dubbed the "Planet Earth and Space Conference."

Rising to the Occasion

From the outset, we saw this as a perfect opportunity to start a constructive and productive "conversation" with the environmentalist community. Two of us on the committee, Lorreta Whitesides, wife of NSS Executive Director George Whitesides, and myself are dedicated members of both communities and have insight into why, both groups, equally dedicated to preserving our home world, continue to talk past one another. We come from different cultures. Lorreta and I separately listed areas in which we thought conversation might be especially fruitful, and with that input, Peter Schubert drafted the specific proposal which was endorsed by everyone on this ad hoc committee.

We then approached a "bridge group," the Earth and Space Foundation whose leaders are personal friends of the Whitesides. They enthusiastically cosponsored the proposal. We managed to get the sponsorship of an environmental group also just in time for the January 8, 2008 first (of 3) submission deadlines.

The Waiting

We are awaiting word from EPA, that our proposal is accepted. This conference, if approved, and if successful, would bring together two constituencies that while driven by different cultures, are both focused on preserving Earth for future generations.

The conference will address individual and local here & now approaches as well as long term space-based measures. We would show how development of some technologies needed in space will help here on Earth. If this conference goes forward, and is successful to the point where we want to do this every other year, that will be a big feather in our cap, promotion wise.

This conference may include workshops focused on potential benefits here and now of predevelopment of some of the technologies listed in the "Game Plan" above, as well as of biological life support issues and biosphere sustainability technologies. If we can get even some elements of both very stubborn constituencies to start talking to one another, that will be an achievement.

Until we get a positive response from EPA, we are postponing talk of "when" and "where" such a conference might be held. To do that now would be to get ahead of ourselves. It won't be in conjunction with and ISDC!

We will keep you posted. PK

MMM # 248

IN FOCUS The Moon: What's in it for Earth?

By Peter Kokh

, To most people, the Moon is a pretty sight, even romantic, but otherwise quite irrelevant. We need to show them how and why it isn't so, that opening the Moon is very relevant to us all.

To do this, we need to we need to firm up our own understanding of "**What's in it for Earth?"** Below are some key talking points. We may add to this list, and we will expand on each in upcoming articles, starting in this issue.

- **Continuing our Frontier-opening saga:** Humanity's "home world" is Africa. Over more than a hundred thousand years, we have expanded to one continent after another. This expansion has increased our cultural diversity, and, more importantly, our capacity to adapt to frontiers with differing sets of resources, and different plant and animal species. This Epic has demonstrated the all but unlimited capacities of the human endowment to adapt. In many ways, the Moon is just another continent across another kind of sea, and it is part of Greater Earth. Not to open the Moon would become humanity's first significant failure.

All past generations of youth have enjoyed the options offered by new frontiers. Do we have the right to close the frontier door for generations of youth to come?

- **Booster shot for World Economics:** The Moon is the ideal and most environmentally friendly source of raw materials with which to realize the maximum economic potential of GEO, already a significant contributor, nearing $300 Billion a year, to the world economy, through various kinds of satellite operations.

  It would take 1/23rd the rocket fuel to bring needed materials down the gravity well to Geosynchronous orbit as it would to bring them up the well a much shorter distance from Earth - and without the air pollution so many rockets might create.

- **Technologies for Healing our Environment:** Sadly, to many people, the ever-increasing degradation of our environment is not a pressing concern. Yes, we worry about passing on to our children a shattered economy, but not about passing on a shattered environment.

  There are several ways in which opening the Moon can help on both fronts. On the Moon, pioneers will live "downwind and downstream of themselves." There will be nobody else's back yard to dump in. The pioneers will have to learn to live in harmony with nature within their mini-biospheres under pain of death. We can learn from them what we would never bother to learn for ourselves because we do not feel the ill effects of our bad stewardship in the near term.

- **Zero-G Exports from Lunar bases and settlements:** Some, many in fact, doubt the economic feasibility of developing usable construction materials from moon dust. Not only has most needed research into lunar on location materials languished in the early theoretical stage, but little homework has been done on a step-by-step process to "bootstrap" lunar industries, except by the Moon Society's St. Louis Think Tank.

  Be that as it may, there are some "Lunar Exports" that are immaterial but still of significant economic value. And we take this up in this issue.

The bottom line is that the answer to "the Moon, what's in it for Earth?" is "one heck of a lot!"

PK

The Moon: What's in it for Earth? Part I
Zero-G Export$ from Lunar Outposts & Settlements to Earth

By Peter Kokh

Many space enthusiasts are skeptical about the economic feasibility of producing anything on the Moon to send back to Earth. That's another article, but read pages 6-8 for clues. Here we want to cite those products that "ship free". Know-how processes and technologies that could be developed on Earth, but will not be, as the perceived need is less urgent.

- **Environmental technologies developed first on the Moon where the urgency is immediate**

Lunar Pioneers will learn to live in harmony with Nature within their mini-biospheres, and learn fast, because they have no choice. They will be "living downwind and downstream of themselves" and there is nobody's back yard to dump pollutants, especially organic compounds made of elements scarce on the Moon. The processes and technologies they develop, because they have no choice, can then be exported to Earth and as they are adopted on Earth, make a very critical and significant contribution to the preservation of Earth's fragile environment for future generations.

These technologies will include stale air and used water treatment, products and new production processes that make "total recycling" feasible and easy. They will also produce a mindset, beginning at a very young age, of ingrained personal responsibility to preserve their fragile mini-biospheres.

- **Moon-appropriate building materials and variants that could find a niche on Earth as well:**

As so many of the materials that we use on Earth include chemical elements rare on the Moon, we must make do with substitutions. Glass-glass compo-sites ("glax") is a promising area of research in which only minimal demonstrations have been done to date. We might make habitat modules, furniture, vehicle bodies, and other useful products form this material, which could be pre-developed here on Earth as it has advantages such as a substitute for wood. Read:

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

New types of concrete types; new metal alloys that do not use alloy ingredients rare on the Moon such as copper, zinc, even carbon, are some options. Once developed on the Moon where the need is urgent, such materials may well find a market on Earth in nations less well endowed with mineral wealth.

- **Technology options using elements not rare on the Moon** (i.e. excluding elements rare on the Moon)

Even given confirmation of surprisingly large quantities of water-ice in permanently shaded craters at both lunar poles, and recent evidence of unsuspected quantities of water bound up in lunar materials in micro-drops, water will be harvested with much greater effort on the Moon than on our water-rich planet. New ways of conserving water and recycling it with ever-greater efficiency will be an effort that is pursued religiously as need grows with population.

As to mining, pioneers will treat the tailings with respect, as they are necessarily enriched in all elements not yet extracted. When no more elements can be affordably extracted, pioneers will find ways to turn these last-generation tailings into products that are useful. And some of the technologies and processes so developed will help reduce our "trash problems" here on Earth. The "**throughput**"* footprint of the settlement is thus reduced, with the result that population for population, the lunar landscape will be far better preserved than has Earth's been. And perhaps some of these technologies applied on Earth could in time "recover and restore" significant portions of industry- and wastes-wrecked lands here on Earth.

* The percentage of raw materials mined
that ends up in landfills as a negative indicator

To conserve energy, lunar industrial parks may be arranged so that waste heat from those operations that require higher operating temperatures supplies those that need somewhat less, in a "**Thermal Energy Cascade**". It would make sense to design industrial parks on Earth to do likewise: reusing and reusing waste heat, which is potential energy.

- **Education of youth in environmental responsibility.**

The lunar settlement experiment will surely fail if living right, given the strictures of the lunar environment does not quickly become "second nature," and anything but a resented burden. This means raising children and youth accordingly. **A "4th R" ~ recycling**, must be added to the curricula. Assigning recycling chores, a year of "universal service" in the water/air treatment systems or in bio-waste recycling operations would make sense. Survival is at stake.

- **Art Form Options that work on the Moon/Mars, will also work on Earth**

Art forms that are totally inorganic will have their own unique beauty and could catch on here. Check out:

http://www.moonsociety.org/chapters/milwaukee/painting_exp.html

- **Social Experiments to maximize productivity of all inhabitants**

Making a frontier economy work will depend on everyone doing their part: no room for slackers and/or those who add to the burden. This means taking cradle-to-grave steps to minimize anti-social behavior. "Out-the airlock" solutions may seem severe, but chain-gang labor should not be dismissed for the stubbornly uncooperative. Handling the handicapped so that any burdens are offset with plusses will be a challenge. The lessons for Earth will be significant.

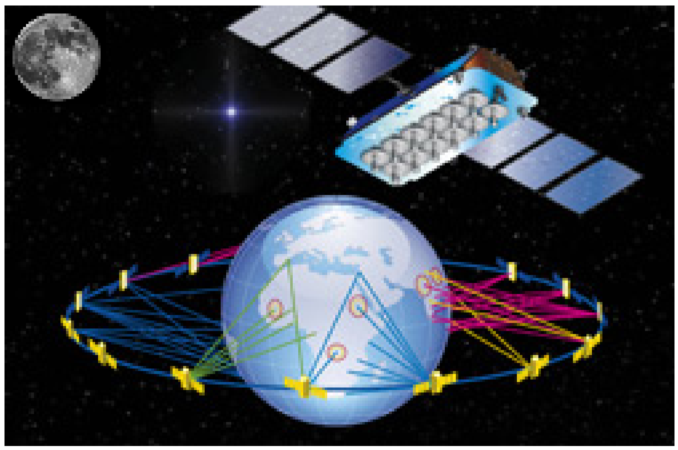
- **Retirement must mean switching to more relaxed forms of productivity.**

Better child-care options (such as preretirement part time grand-parenting?) are needed to free adults in their prime for economically productive activities. Retirement should be a transition to other forms of productivity freely chosen

The above is not meant to be an exhaustive list of “Zero-G Exports from the Moon to Earth. **PK**

MMM # 249

The Moon: What’s in it for Earth? Part II: Lunar Materials to Grow Earth’s Economy

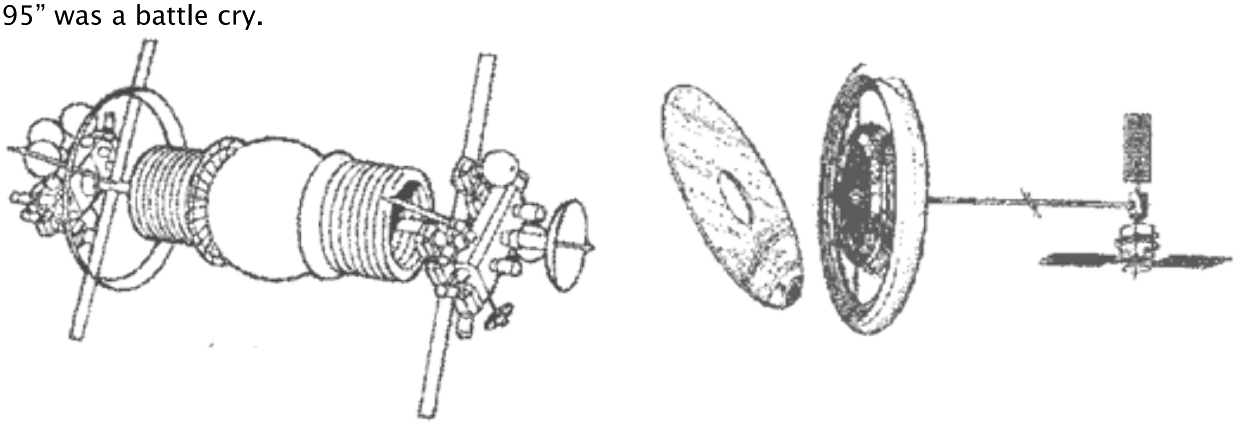


(Photo Credit: Briot/Thales Alenia Space), Moon image added

By Peter Kokh

How the Dream began

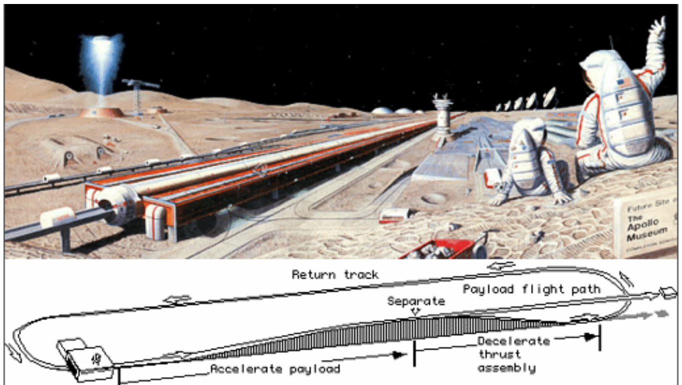
In the early 1970s, Princeton physicist Dr. Gerard K. O’Neill publicized a scenario in which we would go to the Moon, mine lunar materials near the equator and sling them into space with an electromagnetic “mass driver.” There they would be used to build space settlements to house workers in comfortable and pleasant surroundings, workers who would use more lunar materials to build hundreds or thousands of gigantic solar power satellites to feed our planet’s ever more voracious appetite for energy. Thus began the L5 Society. “L5 by ‘95” was a battle cry.



Left: Bernal Sphere (Island 1) and **Right:** Torus (Island 2, above

In response to Congressional requests, NASA even produced a comprehensive "**Space Resources and Space Settlement**" report in 1977 on the scenario and related ideas for Congress. It is still worth reading and belongs in every space enthusiast's library.

While the scheme was logical, too many of the needed technologies were still in the conceptual stage. To their credit, O'Neill's Princeton team produced successively three working model mass-drivers, each progressively more powerful and convincing.

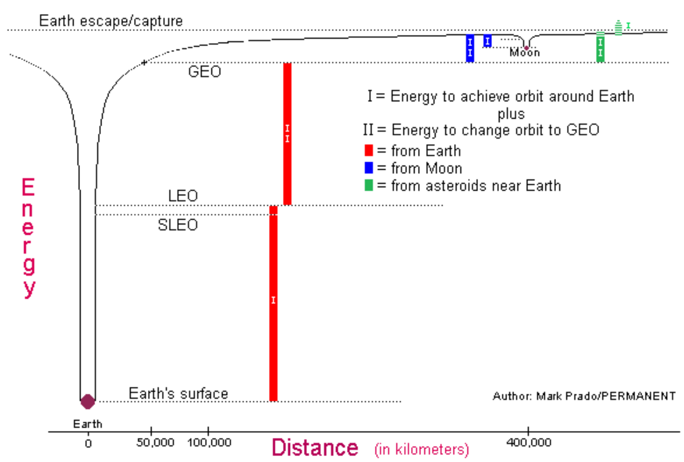


A mass-driver is a means to use solar power to accelerate cargo pods to lunar escape velocity without the use of rockets or rocket fuel, best-located on/near the equator.

Read **http://www.nss.org/settlement/L5news/1980-massdriver.htm**

The logic of using "lunar materials" to build giant structures in Geosynchronous Orbit is impeccable: it would take only 1/23rd the fuel to "downport" (down the Earth's gravity well) material's from the Moon on the gravity well's shoulder down to Geosynchronous Earth Obit as it would to "upport" them up that steep slope the much shorter distance from Earth's surface. And this, goes the logic, would make solar power sats much less prohibitively expensive.

It is the unique economic potential of Geosynhronous Orbit (Economic Gross Product as of 2010 c. $275 Billion) that makes the existence of potential construction materials on the shoulder of Earth's Gravity Well so significant. The Moon and GEO are a natural team literally "made in heaven." This is a 2-way economic case of **"Location, Location, Location."**



http://www.permanent.com/images/t-gravity-wells.gif

Enter The Giggle factor

Many of those old "L5ers" are still around, including this writer. But others, also convinced that Earth's future depends on Solar Power Satellites, but not spiritual descendents of O'Neill, are reluctant to back plans that call for lunar sourcing of materials. It will take too much of an effort, gobbling up too many years of lead time, to industrialize the Moon to the point where lunar raw materials could make a signify-cant and timely difference. And on the NSS

Space Solar Power Committee, this division between O'Neillian believers and those never caught up in the L5 Space Settlement dream is quite obvious, with both sides talking past each other.

Long overdue critical distinctions

1. **Distinction between parts made on the Moon and those made here on Earth** – this part of the puzzle's solution is something I contributed way back in MMM #19, September 1988, pp. 3-4, "**A Strategy for Following up Lunar Soil Processing with Lunar "M.U.S./c.l.e."** – In this plan, we would seek to produce on the Moon everything needed there that was **M**assive, **U**nitary (we need many of the same), and **S**imple. We would produce on Earth for up-shipment, things that are **c**omplex, **l**ightweight, and **e**lectronic. Now there are sure to be many things that do not fall neatly into one of these two divisions. But if they can be divided into "MUS" and "cle" subassemblies, then we have the problem of sourcing solved neatly. : Basic simple lunar industries will produce the lion's share of what is needed weight-wise while terrestrial industries will provide the rest. This article is online at: http://www.moonsociety.org/publications/mmm_papers/muscle_paper.htm
2. **Lowering the expense of developing "in situ" lunar resources into usable building materials** – this is a challenge we addressed even earlier, in MMM #16, June 1988, pp. 3-5, "**Glass-Glass Composites**" in we suggested that just the opposite of the "spin-off" process, "**spin-up**" would yield prototypes of technologies needed on the Moon or elsewhere in space at much less research and development cost. Here, instead of a high-cost NASA crash program, entrepreneurs examine the list of needed technologies and examine each for possibly profitable terrestrial applications, then pre-develop those technologies precisely for those terrestrial uses. This article is also online at: http://www.moonsociety.org/publications/mmm_papers/glass_composites_paper.htm
3. **Pairing the use of lunar materials with the construction space habitats for workers** – giant hollow structures with artificial gravity provided by rotation makes the combined concept a gargantuan one: attractive, yes, affordable maybe not. We must keep in mind the enormous progress made in robotics and teleoperated systems in the past forty years. We will need people on the Moon and in space, but perhaps at least an order of magnitude (factor of 10) if not two (factor of 100) fewer. That changes the economics already. Dave Dietzler brought this up recently in **MMM #242**, February 2011, pp. 7-8 "**O'Neill's High Frontier Revisited**" – in short, many labor-intensive tasks in space will be performed by robot avatars, partly automated and partly teleoperated from elsewhere.
4. **Building up the needed Lunar Industries** – even given the above distinctions and novel approaches that greatly reduce the challenge of creating an industrial complex on the Moon capable of contributing the major fraction of the mass of Solar Power Satellite construction elements, the idea of lunar industrialization remains "science-fictional" to many. Well the Moon Society has addressed that as well, in our concept (Peter Kokh and Dave Dietzler) for an "**International Lunar Research Park**" – see MMM-India Quarterly [M3IQ] #2 February 2009 p. 20 and MMM pp. 5-6, #224 April 2009. The M3iQ article is online at: http://www.moonsociety.org/india/mmm-india/m3india2_Winter09.pdf
   The ILRP would be fully international, and thus quite resistant to any one nation's budgetary pressures or waning of resolve, witness the International Space Station. The basic enabling parts (spaceport, warehouse, recycling operations, and more would be constructed by a contractor consortium, so that individual national space agencies could ship up their outpost modules and plug in, free to concentrate on the science and research they came to so. Other corporations and enterprises would be welcome. This is the kind of critter that could in time morph into the first industrial lunar settlement.
5. **Identifying feasible lunar materials and how to produce them** – This is a task to which Dave Dietzler and his "ILRP Team" has dedicated itself. What alloys of iron, aluminum, titanium, and magnesium, the four "engineering metals" are feasible on the Moon, given the low abundance of the usual alloy ingredients for each? So far, the team has identified several feasible options and how we can go about isolating the needed components from the mish-mash of moondust in which minerals have not been concentrated into mine-worth lodes,

absent the geological processes that work on Earth in the presence of water. If you have been a reader of MMM over the past few years, you will have seen much of Dave's work.

6. **Switching to more efficient, cheaper space transportation systems** – We have written often over the years about the flawed philosophy of NASA space transportation architectures. First we need orbital refueling. Second we need to design all components for salvageability and reuse, all the way up the line from Earth orbit to lunar landing. The Apollo and Apollo on Steroids approach of Constellation and now its disguised reappearance as "SLS" are insane. Getting into space has to be about getting into space, not providing money for the constituencies of key Senators and Representatives, or catering to the current stable of industrial-military complex providers. The Commercial Route alone holds hope.

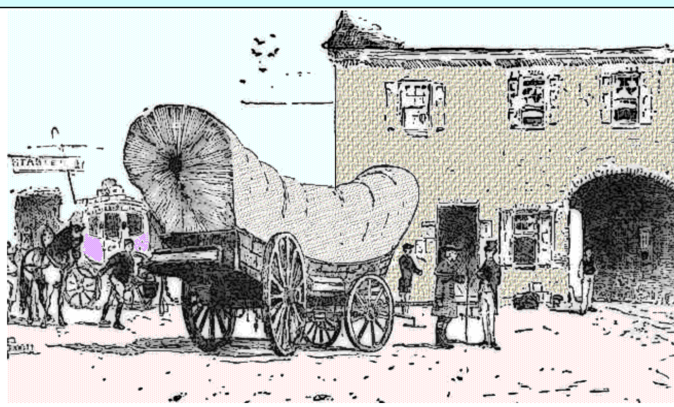
But is anyone listening!

MMM's circulation is worldwide but in very small numbers. We try to make our presence and work known at the annual International Space Development and other Conferences and have used our "University of Luna Awards" to persons doing research along the needed lines, to help call attention. It is an uphill struggle, but slowly, some of these concepts are being talked about. If we are not mentioned that does not matter as it is the ideas that are important.

There is more work to be done, especially in deciding trade-offs between what can be most cheaply made and shipped from whence to where. We are convinced that we are on the right track. **PK/DDz**

MMM # 250

The Moon: What's in it for Earth? Part III:
The Benefits of a Challenging Frontier;
Availability of Frontiers to Settle as a Cultural Stimulant and Safety Valve



"Wild wild west" as a forecast of the "wild wild Moon"?

By Peter Kokh

I can't think of anyone who has better illustrated and explained with due passion the importance of human frontiers beyond Earth than **Robert Zubrin**, since then the founder of the Mars Society. I encourage all to read "The Significance of the Martian Frontier", an article published in the September/October 1994 issue of **Ad Astra** – a publication of the National Space Society. This essay is online at:

http://www.nss.org/settlement/mars/zubrin-frontier.html

Zubrin begins by quoting Walter Prescott Webb from his **The Great Frontier**, 1951:

"It would be very interesting to speculate on what the human imagination is going to do with a frontierless world where it must seek its inspiration in uniformity rather than variety, in sameness rather than contrast, in safety rather than peril, in probing the harmless nuances of the known rather than the thundering uncertainties of unknown seas or continents. The dreamers, the poets, and the philosophers are after all but instruments, which make vocal and articulate the hopes and aspirations and the fears of a people.

The people are going to miss the frontier more than words can express. For four centuries they heard its call, listened to its promises, and bet their lives and fortunes on its outcome. It calls no more..."

Zubrin quotes Frederick Jackson Turner, a young professor of history at the then little known University of Wisconsin over a hundred years ago:

“To the frontier the American intellect owes its striking characteristics, that coarseness of strength combined with acuteness and inquisitiveness; that practical, inventive turn of mind, quick to find expedients; that masterful grasp of material things, lacking in the artistic but powerful to effect great ends; that restless, nervous energy; that dominant individualism, working for good and evil, and withal that buoyancy and exuberance that comes from freedom — these are the traits of the frontier, or traits called out elsewhere because of the existence of the frontier."

He frontier has been slipping into the past. If we do not open new frontiers, we risk our civilization and culture becoming stagnant, ossified, fossilized, an intellectual and spiritual prison.

Yet it is clear that the personal characteristics that lead some to pioneer are not at all universal in our species. It is only certain types of personalities, with certain types of talents, who are so driven. And I believe I have stumbled on the key some years ago.

Here is the gist of my “eureka moment.”

Those raised in, or familiar with the Christian faith will have heard of “the Beatitudes - eight or ten depending on the source.

http://www.searchthebible.com/beatitudes.html

To this list I propose to add another:

Blessed are the Second Best for they are the ones who pioneer new frontiers!

Let me explain. Those who were doing well in Boston and Baltimore in the mid-19th Century stayed in Boston and Baltimore. Those talented and motivated individuals who found all suitable positions taken, no way to climb the ladder, were the more motivated to resettle in the wide-open West where they had a better chance of getting in on the ground floor. Their lives might be hard and difficult, but they would be rewarding, something that cannot be bought.

It was the same with talented and motivated Europeans who found little room to climb where they were, but with enough ability to reestablish themselves in the Americas or Australia and elsewhere. Indeed the paradigm can be found much further back, beyond the beginnings of humankind. Among lions, for example, and in other species, those capable males who were unable to successfully challenge the pack leader but still had leadership traits to offer were the ones who with their mates pioneered new territory and established new tribes.

It is not the best individuals, the cream of the crop, who pioneer. **It is the second best.**

The availability of frontiers, however rough and wild and challenging, has served both animal species (plants as well) and humans as expansion space and as a safety valve from time immemorial. Population pressure is a factor as well, of course.

Meanwhile, new human frontiers soon develop fresh cultures and spirits, that through return visits to the homeland, revitalize stagnant cultures there. The opening of the Americas revitalized all sectors and aspects of European culture and civilization. Feedback from other national “diasporas” has done likewise, though sometimes this feedback is delayed.

Humans are a frontier-blazing species

And this began with the spread of human populations first throughout Africa, then "Out of Africa" to Europe and Asia, Australia and the Americas. The now more than 100 millennia long "**Epic of Man**" has taken us "Out of Africa" to one continent after another.

The Antarctic Exception

So far, Antarctica has been a frontier for explorers and scientists only, fisherman tolerated on the periphery. By international treaty, "settlement" and access to resources are excluded, out of fear that this pristine environment would be spoiled (as we have "spoiled" the other continents – fortunately not in their entirety!

While we have committed our share of environmental atrocities on other continents, that we cannot establish protocols and regimes that would preserve the most environmentally sensitive areas of Antarctic while opening less sensitive regions to controlled settlement and resource use is an assertion that desperately needs to be challenged.

If we allow the Antarctic Treaty to go unmodified, it could become a model for off-Earth non-expansion. Yes, we have sinned! No, **humans can learn and adapt to environment-respecting and cherishing lifestyles and resource-access**. And unless we are allowed to try new paradigms off-Earth, we will be doomed cultural and intellectual stagnation. Then we can write the final judgment on the human experiment right now: "a brilliant start, an abominable failure to continue."

Antarctica would be a great proving ground for prospective Martian settlers, as the climate has nearly identical thermal range. Mars, with less fresh water, no breathable air, and no fish in a surrounding sea, will be the harder frontier. Those who can't make it in Antarctica need not apply.

"Of Dust," or "of Star Dust"

Those of us raised in the Judeo-Christian tradition, are very familiar with the line from Genesis"

"Of dust thou art, and to dust thou shalt return." Yes, but that dust is star dust. Every atom in our bodies with the exception of hydrogen, has been forged in the interior of stars that have since exploded, seeding the interstellar gas clouds with the dust from which everything else has come, including our Sun and its family of planets. In that light, a correction is in order.

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

To close the door to frontiers beyond Earth would be the ultimate perversion, the ultimate slap in the face to our Creator or creative agencies.

Intercontinental > Interplanetary > Interstellar

Further, the Moon is not a sibling planet with its own orbit around the sun. It shares Earth's orbit and is bound to Earth. It is part of Greater Earth, and in a very real sense:

"**another continent beyond another kind of sea**."

We arose as an African species, and have since become an Intercontinental one. Settling the Moon will be the consummate chapter of our intercontinental epic, establishing the Keystone piece that prepares us for phase II: Interplanetary expansion starting with Mars. Then, on to the Stars! It is at once a human legacy, our birthright, and our destiny. And those remaining on Earth will benefit enormously just as those who stayed in Europe benefited form the settling of the Americas.

Lessons learned on the Moon of use on Earth

` Yes, planetary scientists and geologists learn a lot about the Moon that sheds light on the early Earth. But while intellectually interesting and illuminating, this new knowledge is unlikely to be of practical economic significance unless it indicated unsuspected resources in the upper mantle that could somehow be tapped – an unlikely scenario.

But pioneers, forced to adapt to an unfamiliar and a seemingly hostile and life-threatening environment on the Moon, would be facing the biggest test since early Siberians pushed into the arctic and conquered the ice and cold and snow as Eskimos and Inuit. Think of the phenomenal difference between the jungle-skirted plains of East Africa and the Arctic coasts of Alaska and Canada and you have some idea of the challenge that will face lunar pioneers. History says that with the right attitudes, determination, inventiveness and resourcefulness, pioneers can meet the challenge and turn life on the Moon into something rewarding and worth the sacrifices of favorite things about life on Earth that they leave behind.

They will have to develop new alloys of familiar metals, and new materials to substitute for wood and plastics and fossil fuels. In the process, they will come up with things we have never tried on Earth but would make welcome additions to our current stuff-inventories. New art forms, new sports that play to the $1/6^{th}$ G but standard momentum that people on Earth might enjoy watching on TV, and yes, no dance forms too.

It is imperative that pioneers learn environment-preserving processes and techniques without delay under sentence of system collapse whereas we will not spend money and time learning such things as the punishing consequences of our environmental sins are long delayed. “Pioneers will live immediately downwind and downstream of themselves.” There will be no lunar global water and atmosphere sinks to disperse pollutants, only local mini-biospheres.

The pioneers will have to learn to live with mischievous moondust and black skies and 2-week long dayspans and equally long nightspans, unbelievable nightspan cold and dayspan heat, cosmic rays and solar flares.. After some years on the Moon they may have to face the fact that they might not be able to readapt to life on Earth.

But they will not be alone. Pioneers will have brought along plants and animals, establish little “gaiacules.” We must reencradle ourselves in pocket offspring of “Mother Earth.”” Thus the pioneers will be spreading Earth Life (“Gaia”), not just humanity. To the extent that there is no other way for Earth-Life ecosystems to reproduce themselves beyond the atmosphere, humans are essential to any such reproduction. This gives settlements on the Moon a double mission, a mission with a significance that transcends human history. If we are children of Earth, we return the honor in midwiving mini-Earths wherever we go.

The effects and benefits on the life and culture of those who stay behind will be enormous. **PK**