"Expanding the Human Economy through Off-Planet Resources"

MOON MINERS' MANIFESTO

MMM Classics
The First Ten Years

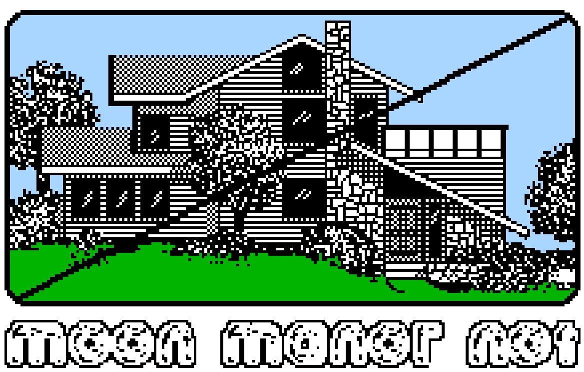
Year 8: MMM #s 71-80
December 1993 - November 1994

We begin the year with the second and third installments on our report on the ISDC 1993 Huntsville **Workshop: Asteroid Base Design**. The workshop split into three teams to tackle "A Permanent Main Belt Service Center on Ceres" [MMM #70], a "Mining & Shipping Outpost on mid-size Gaspra," and a "Mass Driver Rig on a small astrochunk."

But then, after our annual Mars Theme issue, we tackle a topic of interest to anyone whose dream takes them beyond establishing a human beachhead on the Moon, to actual pioneering. **What will Lunan settler homes be like?** To all outside appearances, nothing like what we are used to here on Earth!

First, settlers will not have a biosphere in place to take for granted. Second, many of the building materials and construction techniques we have at our command will not be available to them.

Yet using those building materials that can be produced on the early frontier, appropriate technologies and, above all, resourcefullness and ingenuity, they will indeed be able to make themselves at home.



Beginning in MMM #74, we begin with articles on "Shielding & Shelter," "Visual Access," "Sun Moods," "KGB [Kitchen, Garden, Bath] Cores," and a "METE [Modular Element Testbed Ensemble] Subassembly Project."

Continuing in MMM #65, we explore the realm of "Lunar Appropriate Modular Architecture.'

In MMM #66, we take our crystal ball inside the interior of Lunan homesteads, tackling the Manufacturing and Assembly of "Interior Walls," and "Wall Surfaces and Trimwork," and the problems and solutions Lunan homemakers will face in putting decorative items "On the Walls." How we will make "Ceilings" and "Flooring" is also discussed.

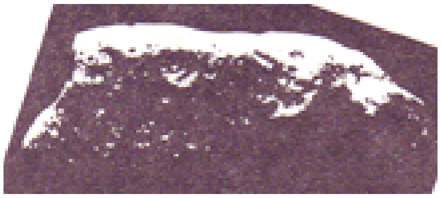
Then, in MMM #67, we take up the subject of "Furni-ture" and furnishings, "Upholstery Fabrics," "Sculpture," and "Wall-hangings." A short article covers "Art du Jour," the temporary art created by children. The emergence of Cottage Industries to serve the strong home-stead furnishings and decor market is also discussed. This issue also is the first to mention our "Water-glazing Project" to create make-do Lunar-appropriate "paints" from metal oxide pigments suspended in sodium silicate, the only known liquid adhesive "waterglass." The first painting in this media, "Moon Garden #1" is described in MMM #80. Meanwhile, issue #77 also first mentions our "Lunar Homestead Show" project to create a traveling exhibit illustrating and demonstrating all these ideas, with the intend of staging a grand debut at ISDC 1998 in Milwaukee. A few items were completed for that event, but time, money, and the need to concentrate on other items got in the way of that ambitious scheme.

In MMM #79. we turn to another of our favorite topics, **"Rural Luna"** with articles on "Lunar Roads," "Waysides, Service Centers, and Inns," and "Lunar Vehicle Design Constraints."

We close the year with a three part report on another Workshop series also conducted by the Lunar Reclamation Society "Mission Control" Team, this time at the 1994 International Space Development Conference in Toronto, our topic: **Space Tourism.** Mark Kaehny led the team that discussed possibilities for "The First Spacetourist Flights." George French led the team that brainstormed "The First Space Hotel." Peter Kokh led the team that brainstormed "An expandable Luxury Earth Orbit Hotel-Resort."

MMM #71 - DEC 1993

Asteroids Shapes, Mining, and Relics.



At left is our first photo of 243 Ida, taken by Galileo. The largest asteroid seen up close to date, its elongated shape betrays its low mass and gravity, much too weak to pull itself together into a ball. The effect is a world where up and down is often quite askew with the lay of the surface. See "'Stroidbits" below. Our report on the Huntsville Asteroid Base Design Workshop continues in this issue. And for a look at asteroids already recovered and conveniently cached on the Moon see "Astroblemes" below.

Tale of 3 asteroids

Part II of a three track Mission Control™ Workshop at the '93 Huntsville ISDC;

Peter Kokh* with Mark Kaehny, Bill Higgins, et alii

Group 2:

A Mining & Shipping Outpost on Mid Size Gaspra

Workshop "Primer"

Starting Point: Consider:

There is some level of false expectation about how rich the ores might be on various asteroid bodies. This hope comes from the now discredited notion that the asteroids are the debris of some former hapless planet that blew up between the orbits of Mars and Jupiter and that had previously differentiated into an iron rich core and mantle and crust areas. At the same time, it is clear that some of the original "planetesimals" did undergo some sort of differentiation, if not from the heat of radioactive uranium and thorium etc. as on Earth, which have relatively long half-lives and take a long time to heat up the masses in which they are embodies, then possibly something with a shorter lifetime such as radioactive Aluminum 40. This seems to have occurred on Vesta at least. We also have evidence from meteorites that some parent asteroid bodies are ore-enriched. Some of these will be too big to herd back Earthwards by mass driver.

These mid-size bodies will have negligible or 'micro'-gravity environments. Gravity there is enough to keep undisturbed items in place, but insufficient to facilitate human locomotion, or to be much of a mechanical assist for mining and processing. If people are to be stationed there for any length of time, some sort of appropriately sized rotating facility in which they can spend a routine portion of their time may have to be provided if their physiologies are not to adapt beyond recovery to the effective absence of gravity.

Small outposts will likely consist of prefabricated modules, and the use of local resources for add-on construction needs requiring low performance will be minimal.

Your Mission:

Explore, **rate** (discuss, vote, review), **list options**:

◊ Shielding requirements using local regolith soils.
◊ Surface gravitrack or centrifuge or tethered rotating structure to provide at least part time artificial gravity?
◊ Should a Mass Driver be employed anyway to make use of processing tailings to slowly "improve" either the orbit of the asteroid or to make its rotational period more convenient?
◊ Landing facilities for visiting resupply and trader ships or or orbital rendezvous?
◊ What is an ideal population size and gender and age mix and talent pool considering the tasks of such a mining/shipping outpost? Given that, what sort of facilities and functions ought to be provided for education, recreation, etc.
◊ Given all the above, what further design constraints do you see? What are the design options and your recommendations?

Workshop Results: Group 2

GROUP: Bill Higgins, (moderator) Lucien Faust (Author of the report that follows), Clarice Lolich , David Kalman, Welburne D. Johnson II, M.D., and Jay Robinson.

Assumptions:

1. Gaspra (or similar target asteroid) has been probed and determined to have exploitable volatiles, worth mining.
2. Gaspra resembles a potato, about 19x18x12 km, i.e. about 1800 km^3 volume; virtually negligible gravity.
3. Gaspra has a "slow" rotation around one major axis, and little if any wobble about any other axis.(Bill Higgins brought a handbook, but time did not permit a thorough review of its entry on Gaspra. [Ed. actually, little was known prior to the Galileo flyby, i.e. when the book was written.])
4. Travel time to Gaspra, about 18-22 months (8 months via nuclear vehicle proposed by Robert Zubrin'). No calculations were done at the workshop.
5. Supplies are available from cislunar vicinity, and will not all have to be lifted out of Earth's gravity well.

Mission Needs:

Crew - about 18 people, to include many skills, manpower, 3-shift rotation as needed (6 on duty, 6 off duty but on stand by, 6 asleep - this allows some off-time for 'just living" and allows for coverage needed because of accident or illness.) It was assumed that major medical care would not be needed, but that emergency medicines and a substantial medical kit would serve the expedition adequately.
Radiation shelter
Onsite power
Life support - recycling system with biological assist.
Consumables - Air, water, food; food may be part packaged, part fresh-grown veggies (tending the salad garden would provide a therapeutic change of pace while on-station).
Tools - basic and also high-tech: The crew needs the ability to repair anything. Yet the tool manifest should be compact and lightweight. And provision should be made to allow repairs in shirtsleeve environments where possible. Question: what sort or operations are possible without EVA?
R&R [Rest and Recreation] for "off-duty" time. The quality of life must be bearable.

Laboratory; Millwright shop; Refinery equipment
Packing/Shipping facility - Afterthought (Faust): Mission will need shipping containers (tanks) if product is volatiles. [Ed. or the capacity to manufacturer them on site from local materials. This capacity is essential if the operation is to be open-ended!]
Lots and lots of delta-V capability for:

- Journey to target asteroid (Gaspra etc.)
- Matching velocities
- Launching product into translunar trajectory
- Crew rotation to an accessible R&R spot; and to "home"

Afterthought:

(Faust): Should the expedition depend on resupply, or include sufficient energy and reaction mass so the entire crew could move about the Asteroid Belt, visit larger bases, if not all the way home to Earth-Moon space? The mission will need sufficient reaction mass/energy to ship its product, unless it depends on an "ore-boat" which visits only after sufficient "mined" product has been accumulated.

[**Editor:** it seems highly unlikely that asteroid belt missions, whether specifically targeted or seeking successive targets of opportunity, will ever be launched unless equipped to produce fuel on site from any of the major types of local resources. Such a facility would be marginal at Belt distances if dependent on solar power, but quite feasible with a small "nuke". Taking all the fuel along from Earth *or* Moon would be prohibitive, if not impossible.]

Elaborating on the Above

Crew skills: First Phase tasks will include initial on site analysis of Gaspra's mineral resources and assembly of habitat and mill/ refinery. This phase might occupy 6 months. Skills needed next could come with a relief crew tasked with more detailed phys-ical and chemical analysis, mining, producing, and/or refining "product", packing and storing it, and launching it towards near-Earth recovery areas. Both teams need pilot/ navigator skills and personnel with medical/emergency skills.

Duration of "tour": Each mining crew's tour might last 5-6 years, with one-third arriving about every 20-24 months, with needed renewable supplies. Crew members might renew their tour for up to 10 years. The minimum period of base operation is assumed to be about 10 years.

(Kalman): The team discussed desirability of some effective combination of suspended animation and yoga, to reduce metabolic consumption during trips out and back. The need, desirability, and reliability of such technology needs a great deal of exploration and discussion. [Editor. Current thinking is that simply to minimize total radiation exposure, trips of more than a few month's duration are unacceptable - and that therefore missions to Mars and the asteroids will use nuclear power or not be undertaken at all. Shorter trip times will greatly reduce this en route consumption problem.]

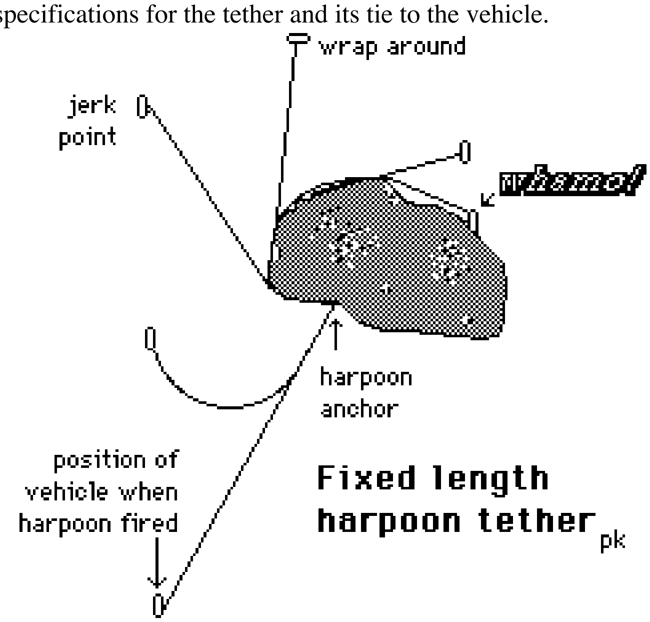
(Faust): Tour length could also depend on the success of recruitment efforts and on the training of replacements; the "reenlistment bonus"; crew members' ability to adjust to fellow crew members, tolerate limited environments, and postpone gratifications; and the rate of compounding of deferred compensation "at home".

(Faust): Depending on demand and value of product, the base might be in operation for just a few tours, or even for generations. Extent of economically recoverable materials (demand market), durability of airlock and other seals, equipment, life support system and power supplies in the deep space environment, security of resupply, lifespan of support organization, care for leadership and selection of compatible crews - all would affect how long such a base might last.

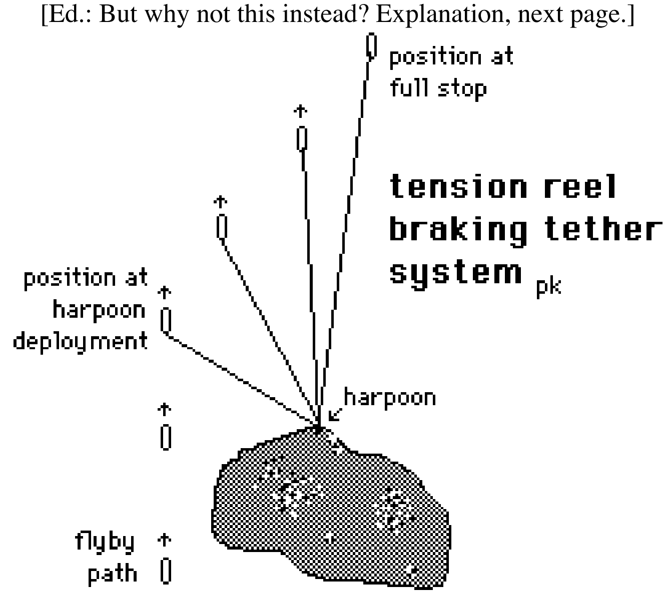
Arrival and method of braking:

a. Normal retro-braking: could begin slowly at the midpoint of travel, or could be at higher Gs towards the end of the trip.

b. Tethered penetrator: As vehicle flies by, it could "harpoon" Gaspra with an anchoring device on a high-tensile-strength line and convert its velocity to a tethered orbital form. Some members were concerned that 1) the moment of impact would strain the "saddle horn", i.e. bring on too-sudden a g-force jerk and/or 2) the tether would wrap around Gaspra and bring the vehicle to final contact at the surface with excessive velocity. The benefit of this method is reduced travel time, with braking concentrated at the end of the trip. Concept needs considerable development as to anchor mechanism and reliability, and the specifications for the tether and its tie to the vehicle.



[Ed.: But why not this instead? Explanation, next page.]



[Editor. Of itself, it would seem a tether would only revector the momentum of the incoming ship, not reduce it. Why not consider how a navy carrier jet is stopped by a flight-deck tension-reeled cable? You'd have to fly past the target asteroid, harpoon its back side, and then pay out the cable, gradually applying the brakes. Questions: Can a secure enough harpoon be devised that the great momentum of the ship wouldn't simply pry loose? How much heat would be produced in the shipboard tension reel and how would it be dissipated? How many kilometers of cable would be needed and would the mass of cable involved be less than the braking fuel avoided?]

Sources of operating energy:

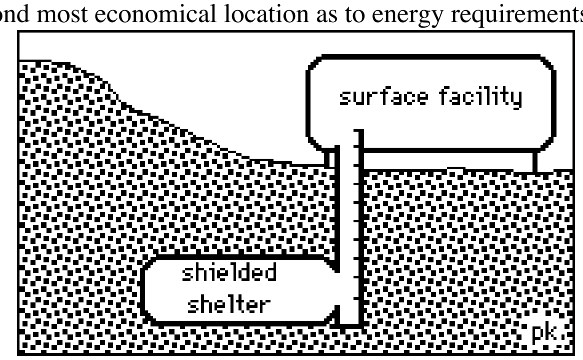
a. Nuclear reactor: standard fission type or He-3 fueled fusion.

b. Solar-voltaic: solar panels in this vicinity would gather only about a sixth of the solar energy available in Earth-Moon space so they'd need to be proportionately large. (1) panels could be deployed near Gaspra, keep station, and beam power to the base, with the disadvantage of reaction mass/fuel for station-keeping and orientation [Ed. why not a Gaspra-synchronous site which would need no such fuel?] or (2) in the negligible gravity, a large tower could be installed with extended panels, with the problem of maintaining orientation depending on Gaspra's rotation system. Afterthought (Faust): cable-linked leaf-like solar panels might be deployed all around Gaspra's equator [circumference c. 60 km) so that no matter what Gaspra's attitude, there would be enough exposure to solar insolation for operational power needs.

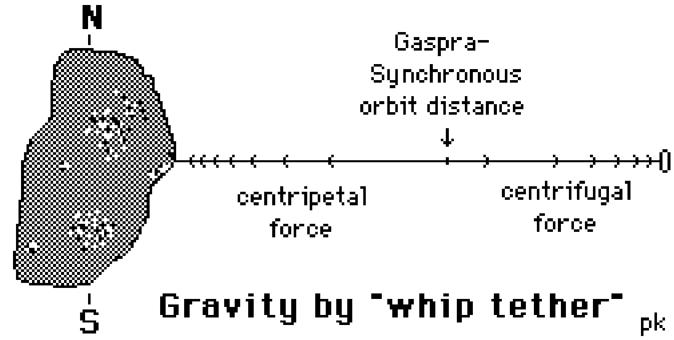
c. Mass-converter. Direct mass to energy conversion is too hypothetical a prospect to merit attention at this time.

Location of base:

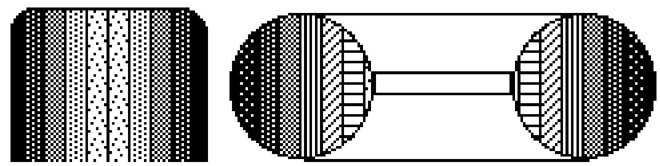
a. On Gaspra, anchored to surface, but with radiation and flare shelter bored into Gaspra to a sufficient depth; this may be the second most economical location as to energy requirements.



b. Tethered at a distance [past Gaspra-synchronous orbit] such that Gaspra-locked rotation will provide for a fractional gravity, for long-term health of miners; winch a vehicle along the tether to go to work or to reach radiation shelter. Low-energy method of obtaining at least a fractional g may be essential to preserve bone mass, fluid distribution, and similar human physiological essentials. A fractional g for extended periods, by rotation, elastic resistance, or other means, is probably a necessary aspect of life support. This solution might develop from the "tethered penetrator" braking approach, and may be the lowest-energy solution. {Editor, assuming Gaspra's mass but not knowing Gaspra's rotation period, a calculation of its synchronous orbit height and thence of the length of the tether needed can't be made. I'd assume we are talking 30-50 km.]

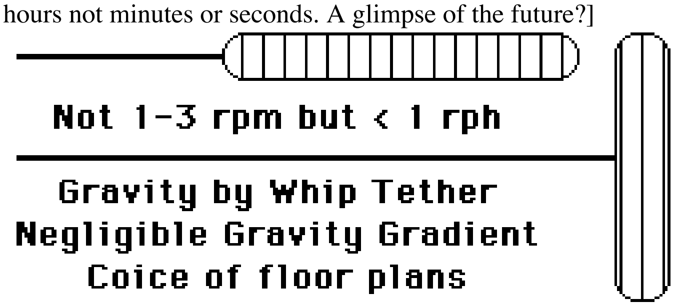


[Ed. cont.: This is an ingenious and elegant solution. In the classic space settlement design, a sphere, torus, or cylinder of substantial radius (1,000 m or more) rotates at 1-3 rpm. There is a noticeable gravity gradient as one climbs inwards towards the axis, or descends toward the periphery. The large radius is needed to produce the desired gravity (1 G or 1/6 G) at tolerable rpm rate. Faster rates result in disorientation, dizziness.]

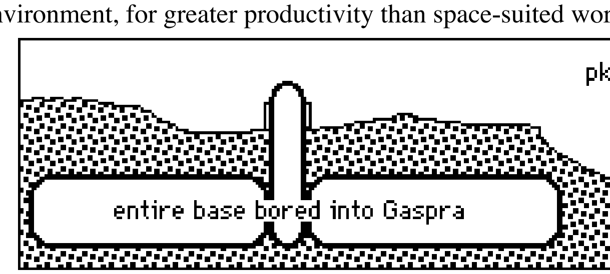


Gravity Gradient Cross sections of rotating Cylinder and Torus

[Ed. cont.: With a whip tether, however, the habitat or vehicle can be small or large and the floors can run any way so long as they are perpendicular to the tether. There is no noticeable gravity gradient. And the slow asteroid-linked rotation takes hours not minutes or seconds. A glimpse of the future?]



c. Entire base bored into body of Gaspra (no estimate of energy needed to do this). Has advantage of radiation shielding close at hand, enlarging living and working areas with a shirtsleeve environment, for greater productivity than space-suited work.



Consumables and life support:

Fuel, reaction mass, air/oxygen, water, food, repair materials, and machines, spare parts and "stock", back-up materials and manuals and recreational materials including musical instruments, all need to be taken in sufficient quantities. Recycling of air and water, food and human wastes appears to be essential to keeping take-along mass in bounds.

Amplification (Kalman): A first, automated mission might deliver supplies and consumables with less on route consumption than a the manned mission. [Editor: as in Dr. Zubrin's Mars Direct scenario, a first uncrewed mission could deliver a reactor and chemical plant to process local volatiles into the consumables that the crew would need in greater abundance upon arrival.] (Team): as many automated missions or craft as necessary might be used for risk reduction, redundancy of supplies. Not everything anticipated may be needed. The other error, leaving out something essential, may be the worst.

Afterthoughts (Faust): A pure "plumbing" system [chemical-mechanical recycling?] probably needs to be supplemented by biotic systems, i.e. plants and bacteria and grow lights to recycle oxygen, purge carbon dioxide, scavenge and reuse human wastes, and grow "fresh" food. The mass, volume, maintenance/training needs and robustness of the two types of systems over the required periods of time need careful review and comparison.

A communication capability and a voluminous technical and cultural library of an evolved CD-ROM type should be taken along. Role-playing and other interactive games may need supervision of psychologically trained crew member(s) to moderate interpersonal relationship strains.

Workshop Postscript: (Faust)

Clearly our team was a self-selected "grab-sample" of attendees at the Huntsville ISDC, rooted in the "here and now", not yet thinking of our task from a projected perspective of members of a successful spacefaring society; and with only a smattering of the basic information needed for our task. We had a doctor, a physicist, a city planner, a teacher, and two kinds of engineers; we lacked such useful perspectives as those of a contractor, a foreman, a submariner, a construction worker, a miners, a test pilot etc.

Last May when the workshop took place, Biosphere II had not yet cracked open. No one knows yet the workable proportions of air to soil to large animal [humans] to bacterial mass, for a long-term mission in such an environment. Offhand, probably we need more air mass than we think. And we probably need ways to keep down rusts and algal blooms and mildew and such.

As yet we have no economics. We can only speculate who might pay for exploration, for the journey out, for shipping product back, for the trip home, and retirement benefits and in what coinage; but we think it will be expensive.

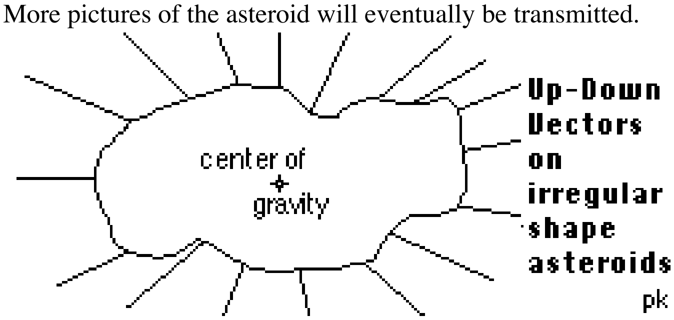
No one has reviewed the oceanic exploration analogs; might our leader be a Captain Ahab, a Captain Bligh, or a Captain Cook? Once people are out there, the High Frontier will be a bigger romance than sail, the railroads, and aviation all combined. But the world needs cheaper launch capability for that to open up. Perhaps the old game of China-goads-Japan-goads-America-goads-France-goads-Russia is a viable game, and nationalism on Earth has a high purpose. **LF**

"THE BEST WAY TO PREDICT THE FUTURE IS TO INVENT IT!

'Stroidbits

243 Ida and Galileo:

The photo of Ida on page 1 is a photomosaic of five frames. Ida was 274 million miles from the Sun (three times the Earth's distance) at the time. Ida is quite a bit larger than Gaspra, visited two years ago by Galileo, but is even more irregular in shape. Plumb lines hung over its surface would show crazy angles, revealing the elongated ends as "hills". But since the gravity is so minimal, visitors would hardly notice. More pictures of the asteroid will eventually be transmitted.



Geographos & Clementine (O'Neill probe)

The next asteroid visited may be 1620 Geographos, an Earth approaching asteroid (named in honor of the National Geographic Society) which came to within 5.6 million miles of Earth in August, 1969. Its next close approach was in '83 when it came to within 8.4 million miles. If the Air Force's Project Clementine O'Neill probe is still functioning after its scheduled January through April lunar polar orbit mission, it is to be redirected to Geographos and put in orbit around it. That would be a first, and would allow the first in depth study of any asteroid, including a mineralogical assay and map. Geographos orbits every 1.39 years and ranges between 0.83 and 1.66 Earth's distance from the Sun.

The "Telurgosphere" or Teleergosphere

What are the practical limits of teleoperation? SSI, Space Studies Institute, has experimented with teleoperated robots with a built in 3 second delay in operator command, device response times. It's a tricky thing to catch on to, but it is possible, and as you may have guessed, kids get the hang of it quicker. We've confirmed our suspicions that teleoperation of some kinds of lunar equipment from Earth is a viable option.

But what about doing the same thing on asteroids temporarily in the vicinity of Earth? How much of a constant response delay can teleoperators master? How far out can this technique be used before the delay length becomes impractical to manage? Five seconds gets you out to twice the distance of the Moon. It is rare asteroids pass that close. At the other extreme, no one imagines Earth-based teleoperation to be an option for Mars and its moonlets, where the delay would be in the 6 to 40 minute range. A simple set of experiments could reveal the limits of this technique. It's something we need to know in order to plan efforts to access asteroidal resources.

This would make a nice chapter project. MMM

[Helium-3 and other Solar Wind-derived gases are not the only

"Settlement Dowry" from the heavens set aside over the eons!]

ASTROBLEMES

[pronounced: ASS troh BLEEMs; Greek: "star wound"]

Why travel long and far to retrieve asteroid resources? They may be already accessible, to lunar settlers at least, with no DV at all!

By Peter Kokh

The Asteroids have landed! The asteroids have landed! So might the headlines of the Lunar Frontier Times read one day as ground truth surface expeditions confirm orbital remote sensing indications of atypically metal-rich ores in isolated areas on the Moon's crater-pocked surface. It has been known with certainty since the return of the first Apollo Moon Rocks that lunar craters are the scars of prolonged episodes of savage celestial bombardment, not of wholesale volcanism. Yet the same rocks show that the overall composition of the surface reflects that of the native crust. No economically noteworthy relics of the intruder astrobits have themselves been found.

In general, this is to be expected. The run of the mill impactor is more likely to be a sort of asteroid classified as a carbonaceous chondrite: largely stony with some hydrate volatiles. The stony component would be difficult to distinguish from the Moon's native regolith soils and have no economic value. Any volatiles are likely to have dissipated into space from the heat of impact. Comet fragments should also have been plentiful, but their gift as well would have been largely squandered. Some cometary volatiles may yet be found in near surface lavatubes and polar permashade regions, though indirect indications are rather discouraging.

But what about the metal-rich asteroids that space development advocates dream about? Shouldn't we find buried intact fragments below many crater bottoms? If so, how deeply might they be buried? In and around Sudbury, Ontario, Canada north of Lake Huron's Georgian Bay, lie the economically significant relics of just such a large and rich impactor.

This oval region 40 miles NNW to SSE and 60 miles WSW to ENE at Sudbury has been a major source of Nickel and copper since early this century. This astrobleme is not the only place on Earth nickel can be found in economi-cally recoverable concentrations. While Sudbury once produced 92% of the world's needs, that figure is now less than 50%. Yet this gift of the asteroids is significant and has definitely accelerated our own industrialization. Less well known are the copper deposits, actually worked first. For every ton of nickel around Sudbury, there is nearly half a ton of copper.

So we're lucky and find a similar nickel-iron-copper rich asteroid relic on the Moon. What would that mean? We have other sources of iron, but if we are mining the astrobleme deposits anyway, a major share of the lunar iron supply may come from such a source. But it is the nickel and copper that would be the real prize.

First nickel: 65% of the nickel mined on Earth is used in producing iron and steel alloys. Here is a partial list with the percentage of nickel in the alloy given. Nickel steels (0.5-10), stainless steels (2-26), heat resistant steels (2-26), nickel cast iron (1-5). Another 15% of nickel production goes into alloys with copper: high nickel-copper alloys (65-70), corrosion resistant cupronickel alloys (2.5-26), heat resistant alloys (78), electrical resistance alloys (80-85) (used in heating elements, rheostats etc.), magnetic alloys (29-90), permanent magnet alloys (14-32), high permeability alloys (45-80), controllable expansion alloys (30-60), nickel "silvers" (10-30 plus copper and zinc), and in nickel coins (25-100). Another 15% is used as pure metal in the food processing, chemical, and radio industries. A handy element, no?

And the Copper! Copper is the basis of the world's first useful alloys: bronze (with tin) and brass (with zinc), instrumental in catapulting humanity out of the late stone age towards the industrial age. It has remained vital to successive layers of technology ever since. It is a much better electrical conductor than lunar-abundant aluminum, and for this reason alone, a major lunar copper strike would be a real bonanza!

The Sudbury site also produces gold, silver, and platinum. These were lesser inclusions in the impacting asteroid and that may be typical. These elements are traditional jewelry stuffs but are industrially vital as well. Could asteroids rich in gold, silver, platinum, copper, lead, zinc and other metals of which the lunar crust holds no handy native concentrations, have impacted the Moon and left us a dowry? In 1986, astronomers discovered a highly reflective object in a near Earth swing on its very eccentric orbit. 1986 DA (a temporary name) is a mile wide object estimated to include 10 billion tons of iron, a billion tons of nickel, 100,000 tons of platinum, and 10,000 of gold. Yet such objects must be rare, and for one of them to have impacted the Moon and left recoverable lodes would be a case of extreme good fortune. We can certainly keep our fingers crossed.

Could we detect metal-rich astroblemes by remote sensing instruments on board future lunar polar orbiters? Perhaps, if the sensitivity and resolution of the instrumentation is high enough. We could easily test and calibrate such an orbital prospector satellite in Earth orbit to see if it picks up the Ni and Cu of the Sudbury site, and with how much detail. Maybe it would discover new terrestrial mother lodes in the process. This prospect alone would warrant the development and launching of such a satellite, perhaps fully paid for by a mining company consortium rather than by government(s).

The most accessible asteroids from a Lunan's point of view are not Nereus (1982 DB) or others in similar orbits but those whose assets have already been hard-landed on the lunar surface. What's the prize? One of the major challenges facing lunar industrial growth and diversification is the lack of mineable ores of the non-engineering metals: **copper, lead, zinc, gold, silver, platinum, etc.** All are indispensable to modern industry and manufacturing, even if the amounts used are quite minor compared to the tonnages of iron, aluminum and titanium. Finding "astrobleme" strikes here and there on the Moon would greatly accelerate the pace of industrial development, greatly improving the Moon's trade balance.

If such endowments are not found, the only options are to "smuggle" such metals in from Earth via "Stowaway Imports" [cf. MMM #63, MAR '93 p.] and/or to support and assist asteroid resource recovery expeditions. MMM

"*YOU* can't go into space!"

√ Twenty-five years after Jamestown was settled...
farmers were spreading deep into Virginia.
√ Twenty-five years after Lewis and Clark...
covered wagons were rolling west.
√ Twenty-five years after the Wright Brothers flew...
people could buy a plane ticket.
But
√ Twenty-five years after John Glenn first orbited the Earth...
space is still "for astronauts only".

Entrepreneurs who want to do business in space can't do it. Scientists who want to carry out innovative experiments can't do it. And artists, writers, teachers, students, citizens... *need not apply*.

Courtesy of the Space Frontier Foundation

[HUMOR on the Airwaves:]
"LEO vs. the Wormhole"

Recently, according to Ben Huset of the Minnesota Space Frontier chapter, a lady called in to a radio talk show to wonder aloud why we needed "another" space station when "we already have one at Deep Space 9". The story gets a lot of laughs, and is then dismissed. A pity.

We did not learn of the talk show host's reply, or of its *tone*, but he might have *respectfully* noted that a space station 'deep in Bajoran territory' guarding the entrance to 'the Wormhole' did not serve immediate human needs in low orbit over our home planet. He might then have gone on to list a selection of those needs *not just as easily* served "at DS-9":

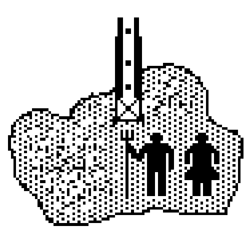
√ monitoring *Earth's* ever changing environmental health
√ learning more about *Earth's* atmosphere, oceans, weather, and crustal movements
√ detection of new energy reserves, other *Earth* resources
√ learning how *terrestrial* organisms fare in zero-G.

Even humorously way-out responses from the uninformed can be an occasion to get across a serious message. **PK**

MMM #72 - FEB 1994

Of Moms & Pops

This month, we finish our series of reports on the Huntsville ISDC "Asteroid Base Design Workshop. One of the most romantic concepts of recent decades has been that of a small crew shepherding a mini-asteroid back to Earth-space where its mineral wealth is needed. Our team takes a look at this idea, below.



Tale of 3 asteroids

Part II of a three track Mission Control™ Workshop at the '93 Huntsville ISDC;
Peter Kokh* with Mark Kaehny, Bill Higgins, et alii

Group 3:
"A Small-Operation Mass Driver Rig *on an Astrochunk to be nudged in to High Earth Orbit"*

Workshop "Primer"

Starting Point: Consider:

1. Potential loot is an appreciable fraction of the astrochunk's mass. The most profitable approach will be to in effect mine the chunk en route, using the unwanted tailings as mass driver fodder, at least until they run out. Upon arrival at L5 or other destination, we will be left with a processed or beneficiated mass of pure or almost pure ore.
2. Meanwhile, the "Mom & Pop" team must have comfy quarters for the long journey, a suitable lab, and a "yolk sack" of provisions to see them through with plenty of margin.
3. Shepherding such an astrochunk may be a trickier-than-you-would-think operation requiring **a**) first stopping the chuck's interfering rotation and **b**) placing the facility so that the center of mass *stays* directly ahead of the mass driver's axis.

YOUR MISSION: Explore, rate, list options:

- ☐ Should Mom & Pop enjoy artificial gravity? What would be an appropriately sized facility for this, and what portion of their routine and tasks should or could be spent within it?
- ☐ Should they have facilities to produce a token but morale-boosting portion of fresh food for their table?
- ☐ What initial food, CELSS, medical, and equipment backup provisions should be stored?
- ☐ What other human considerations need to be considered?
- ☐ What safety considerations need to be taken into account, including shielding, rescue, and/or abort?
- ☐ How do you maintain the flow of material to the mass driver so that the whole astrochunk gets processed en route and only unwanted "tailings" are used as expulsion mass for the mass driver? How does this affect the design of the habitat-lab-maintenance shop part of the setup?
- ☐ Mass Driver aside, what further design constraints do you see? What are the design options and your recommendations?

WORKSHOP RESULTS: Group 3

Report by Mark Kaehny, Group Leader
Also participating: Richard McNeil and John Turner

Moving Flying Mountains (hills really)

Consider a small (+/- 100 meter diameter) asteroid or comet chunk in an orbit in the inner solar system. The goal is to change its orbit and move it to where it is needed - the Earth-Moon system, the Mars system, etc. Ad described in the workshop primer, this is to be a “Mom and Pop” operation of a small number of people who may stay with the asteroid. Is this feasible, and what considerations would there be?

Setting the Stage

First some simplifying assumptions. This takes place in a future with a spacefaring civilization. There would be settlements on the Moon, Mars, and perhaps space colonies in some form. This is the only scenario which might make this economically justifiable. It is assumed that this asteroid or comet chunk (we'll call it the "Rock" from now on) consists in large part of "volatiles", Carbon, Hydrogen, Nitrogen, etc. This probably takes the form of water, hydrocarbons, and perhaps ammonia.

Given this composition a logical destination would be the Earth-Moon system for use on the Moon, or in space colonies. This scenario assumes that the asteroid is small enough that it is better to actually move it, rather than process and ship it. (See the other scenarios for that discussion.) For comparison, this Rock, if melted, would fit into one or two large tankers on Earth. It would fit inside the Superdome. This is the size of object we are dealing with.

There is no appreciable surface gravity. A human can't walk on this object -- he or she would take one step and be in orbit, or actually out of orbit depending on the strength of the step. This means that our rock could very easily fall apart if jarred. That puts a limit on the amount of acceleration that may be applied to it.

Other assumptions that we will make is that we have well designed space nuclear power systems, and an efficient and reliable means to use regular mass (stuff we are getting from the Rock) as reaction mass. The power density requirements for this operation make it look like solar power might not be workable. although some kind of beamed power system instead of nuclear might work. The reaction drivers could be some kind of mass driver, or some kind of "dust blaster" (electrostatic and thermal system) or depending on how materials are processed some kind of nuclear thermal or electric thermal rocket. This would need high reliability (say fire constantly for a month at a time) and high thrust (pump out many kilograms of material constantly).

Technical Questions

Is actually moving an object like this technically feasible, and if so, what are the constraints? The mass of the Rock itself would be used for reaction mass. Back of the envelope calculations show that this a time vs. mass tradeoff. The mass we are discussing is on the order of a couple of million tons of material. To move an object this size from an orbit outside that of Mars in to Earth orbit will either take up a significant amount of mass of the Rock (well over a third) to change the orbit in three or four years, or by using less mass, one can move the it in about a decade.

For the fast route --

- Only nuclear power or some kind of beamed power will have enough energy density for this method. This would not be a small plant!
- The amount of mass to be shifted per day, broken down and used for reaction mass would rival the most efficient mining operation on Earth today in terms of tons of material processed per person per day. (Sudbury type figures are comparable.)
- Machinery would need to run continuously for long periods with little repair or breakdowns.
- The stability of the Rock would become an issue. The center of gravity would be changing, and the stresses might pull the thing apart.

“Mom and Pop?”

All of these problems suggest that a longer transit time would be chosen. In that case the problem of closed cycle life support would become more challenging. The movement and use of local reaction mass will still be a big deal. Moving tons of material, and using it in one of several ways as propellant is not a trivial operation! The group decided that this could not be a “Mom and Pop” operation unless Mom and Pop had a lot of resources available to them. It would most likely be a corporation, or perhaps some kind of wildcatting group. This would mean that they would have some kind of home base somewhere else available to them.

Living on the "Rock"? or Human-tending it?

The previous point led the group to discuss whether the Rock would have continuous habitation. It might be better, especially if the longer itinerary is used, to just have the Rock be human-tended, that is, someone comes to visit now and again. The arguments for this is that consumables do not need to be taken. Even if we assume a quite good closed life support system, the closed system itself is likely to be a quite massive environment. By only having people on the Rock for a short time, this mass is avoided. This assumes fast, relatively cheap and fast passages to and from the Rock of less total duration than the periods when the Rock is unoccupied. Otherwise, of course, the crew might as well stay put.

[Editor’s Comment: But in most cases, especially with Earth-approaching bodies, there is a Catch-22 which works against this idea. The closer two bodies are in their orbital period, the ***lesss frequent*** are the launch windows to and from!]

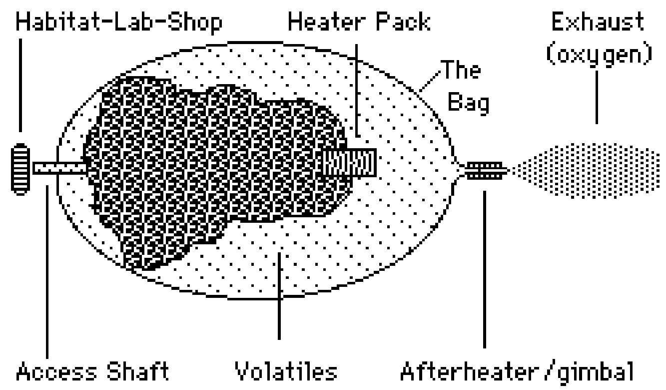
On the other hand, one reason to keep people on the Rock is to start "beneficiating" the materials. That is, separating and processing the valuable stuff. In our example this means the volatiles. This also becomes almost a necessity, since a long transit time in the inner solar system would mean that much material could be lost to the Solar Wind. Also, since one would want to be very careful how this was moved into the Earth-Moon system, it may be that the Rock is sent closer to the Sun into an orbit whose aphelion is at Earths orbit, so that the Rock catches up to the Moon with a smaller difference in velocities. So, as material is used for reaction mass, it could be processed to remove the most valuable components.

However, the massive quantities used might make it more practical just to waste some mass solely as propellant, without using any machinery (which would need servicing). It can't be forgotten that this Rock masses millions of metric tons, this is not small scale for humans even though it is nothing in Solar System terms. Separating materials must be done sometime so to do it in transit time does make sense.

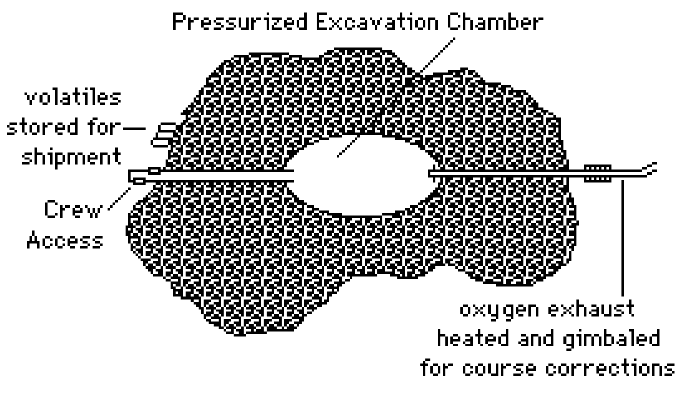
Mine in a Bag

One idea for processing is to "bag" the Rock, that is enclose it in a close-to-airtight container. This wouldn't be that difficult - all one would need is the equivalent of five or six tarpaulins that cover baseball fields in the rain. Obviously they would be made of a much lighter material and thus would make a small cargo. Assume 100 thousand square meters of material (probably far more than needed since a cube 100 meters per side has a surface area of 60 thousand square meters) and 10 kilograms per 100 square meters, which is quite feasible, and we get a total mass of 10 thousand kilograms, about 12 American tons. Not an outrageous mass, and most likely an upper limit.

Given this bag, we can heat up the Rock and separate the gases that are given of with a pump. We can also use this gas (say oxygen fraction, since that won't have a lot of value) as propellant, a perfect source of course correction power.



Another suggestion is to work the Rock from inside out. That is, tunnel inside the Rock, make an airtight (or as close to it as practical) chamber, then start processing the materials in a close-to-shirtsleeves environment. This would allow for much more efficient use of human labor.

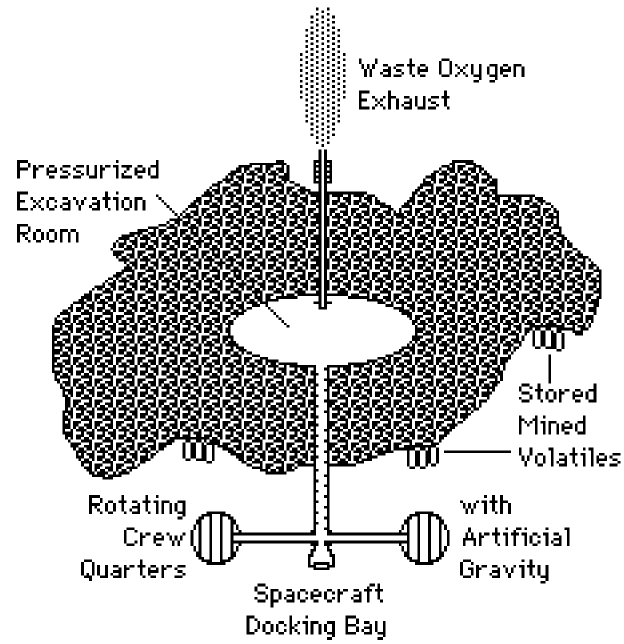


These two ideas work well together, in that the inside area could be over-pressured relative to the outside bagged area, so that if there are any leaks, the inside air is not lost. This provides an extra layer of security for those working inside.

Also even if the inside air was not breathable, if the pressure can be brought up to a reasonable level,workers could just use some type of air-mask, yet still get the benefit of working unencumbered. Just listen again to some tapes of the astronauts working on Hubble, and what they were actually doing, to see how strenuous it is to work in current space suits.

Living Quarters

Given that people will be living on the Rock for extended periods, artificial gravity might be desirable. In this case (and in any other as well) the living quarters should not be on the Rock, but right next to it, connected directly by flexible connections. This allows for people moving around, shifting things on the Rock without throwing the living quarters around as well.



Consumables vs. Yield: Tradeoffs for Profitability

No matter what style mission, a few years or a decade, we must hold the assumption that closed cycle life support systems will be much advanced from what we have now. Otherwise no matter whether the workers stay uninterruptedly or not, the amount of consumables would amount to something tremendous -- several tons per year per person. Since these would be high cost much processed items, they would probably make the whole capture idea uneconomic. This tradeoff will most likely be the determining factor in what type and speed of orbit is taken, what type of "Rock" that is aimed at, etc. Given a very closed system then some of the objections of permanent habitation go away, and this also changes things in terms of propulsion.

A different , better reason for moving the Rock

If we can process the thing where it is, perhaps small motors that just put the Rock in an intersecting orbit could be used, then as the Rock is processed the different products are shipped as the Rock moves. In this case the Rock may never get to the destination, and the reason for "moving" it is to provide more efficient orbits for "freighters". ***MK***

[ED.: One thing this workshop team (nor, to our knowledge, any previous advocates of asteroid moving) did not consider was the *extra challenge* posed to any Rock-moving plans by the body's rotation and axial orientation. *Unless* (illustration below) there are a pair of non-co-rotating mass drivers, dust rockets, etc. at each pole of the body, it may be very difficult to achieve the desired result. It may make more sense to use waste tailings and waste gasses *first* to zero-out rotation. ***PK***]

Why <Tether ——— *Braking*> at Gaspra will work!

by Michael Thomas, Seattle, MMM Contributing Editor

Having introduced the concept of tether braking a few years ago (MMM #30, pg. 11-12) as a means of rendezvousing with Phobos after a craft had aerobraked into a highly elliptical Martian orbit, I have occasionally reflected on the idea of tether braking and problems it presents. The recent second installment of "A Tale of Three Asteroids", in MMM #71, which came out of the Mission Control™ Workshop at the 1993 Huntsville ISDC, poses three critical questions about tether braking. Two of these questions regard technical feasibility and the other regards the economics of the idea. The first question, "Can a secure enough harpoon be devised that the great momentum of the ship wouldn't simply pry loose?", is the most critical. But first let me briefly discuss the others.

The second question asks how much heat the brakes on the cable would generate and how it would be dissipated. This is a straightforward engineering problem and should have a straightforward solution. One idea comes to mind: spray the brake disks with liquid nitrogen and allow it to vaporize and dissipate into the vacuum of space. The third question asks how many kilometers of cable would be required and whether it would weigh less than the fuel required for rocket braking. The answer to this question depends on many variables such as the type of fuel and rockets used (chemical or nuclear) and the tensile strength of the tether. I do not really know the answer to that question.

So why use a tether brake if it does not weigh drastically less than fuel, tanks and rockets? Because it has secondary uses[after arrival (as suggested in the MMM #71 article) such as a space elevator and artificial gravity device (gravity "whip tether"). Another possible secondary use for a tether brake is altering the rotation period of the asteroid to be nearer a convenient fraction of our 24 hour day. If a Gaspra sized body rotated every 7.5 hours, it might be possible to lengthen it to 8 hours. Or it could be used as a rotary mass launcher. If the tether space elevator extends far enough beyond Gaspra synchronous orbit, an object released from it would be traveling at escape velocity and thus be launched into space. With a small body like Gaspra, these uses, rather than weight savings, may be the most substantial reason for developing and using a tether brake. Kudos to the workshop participants for foreseeing that a used tether brake would have such secondary uses! *

The answer to the first question (whether the harpoon will pull out of Gaspra) lies not so much in the design of the harpoon as in the nature of Gaspra itself and the tensile strength of the tether. The more solid Gaspra is the easier it will be to design a "Gaspra harpoon" that will not pull out under the force the cable is able to apply to it. The total momentum of the ship is irrelevant as the tether can only apply so much force without breaking. So the tether, not momentum, determines how much force the harpoon must bear without pulling out. If, for instance, the tether has a tensile strength of 100 tons, and if only 75 tons of force were allowed to be applied to it to prevent danger of breaking, then the harpoon would only have to bear 75 tons of force. The ship could weigh a billion tons and the harpoon would still only have to withstand 75 tons. The great momentum of the ship requires not a stronger harpoon, but a longer tether so it can be gradually decelerated with 75 tons of force. But the less solid Gaspra is, the harder it will be to design a harpoon to hold 75 tons.

So how solid is Gaspra: is it concrete solid or a loose aggregate of astro-rubble? The answer is betrayed in Gaspra's elongated, non-spherical shape. It must have a certain strength to support itself against even it's own feeble gravity. If it were merely a heap of rocks and regolith, even Gaspra's feeble gravity would crush it into a more nearly spherical shape. In other words, Gaspra is an internally solid object. It's longest dimension is about 1.58 times it's shortest dimension. This means that Gaspra's interior contains some very solid rock, something a harpoon can hold onto. It is remotely possible that Gaspra is an aggregate of two or three very solid bodies resting against each other and covered by an obscuring blanket of regolith. But each of these pieces would have to be internally solid and as wide as Gaspra's shortest dimension (about 12 kilometers) or the aggregate would collapse to a more spherical shape. A penetrator harpoon of reasonable design and weight would certainly be able to hold onto Gaspra, Ida, or any other body solid enough to support a non-spherical shape in a body this large (over 15 kilometers.)

A tether capable of pulling it out would have to have a tensile strength very many times that of the rock the body were made of. Once in place, the gravity whip tether could be more permanently and securely anchored with rock bolts, wile the harpoon remained as a backup system should the rock bolts ever be damaged or fail. A cable might also be subject to shearing off at or near the surface of the body due to rubbing against sharp, jagged rocks.

Unlike synthetic materials such as kevlar and spectra, titanium is much harder than rocks and would tend to crush the rocks rather than be crushed by them. Also, lunar titanium might be far cheaper in space than terrestrial materials, and thus titanium may be the material of choice even though it's tensile strength is less than that of kevlar.

In conclusion, a tether braking system for asteroidal rendezvous is technically feasible, and it's economics should be judged not only by it's weight (and resulting transportation cost) but also by the fact that it can serve as infrastructure upon arrival. Using a tether brake as a space elevator and gravity whip will be much cheaper than mining ores and building a foundry to construct a space elevator on site. And without a space elevator, there will be expenses for rocket transportation to and from the surface for humans and "first cargoes" until a mass driver, a space elevator and other means are constructed or deployed. Braking fuel is not the only fuel a tether brake turned space elevator will save, therefore it's weight should be compared with all the fuel it will save. ***MT***

* [EDITOR: On the reusability of tethers. IF, and that's a big if, one's harpoon could be unanchored by some electronic command carried along the tether cable itself, and then the tether reeled back in aboard the ship, it could be reused later in similar fashion at the next destination. Some of the braking energy captured aboard the ship could be used to reel it in. PK]

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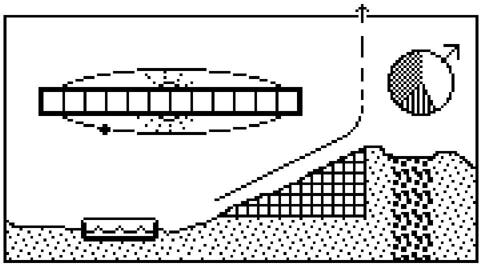
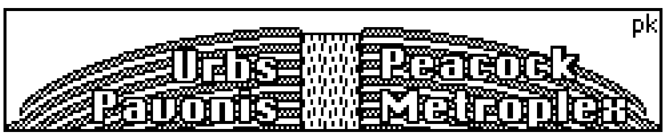


MMM's 7th annual MARS issue

Marsport, Port Scia, Greater Helium - a few of the many names conjured up for fictional cities on Mars. Exploring the overwhelming advantages of one special site, MMM's own crystal ball sees Pavo City and the Peacock Metroplex; *plus* Lowell's List of canal names for future Aqueducts. Two Mars Calendar proposals. A treaty to preserve Martian Heritage: Geological, Mineral, Scenic, Basin, and Corridor lands.

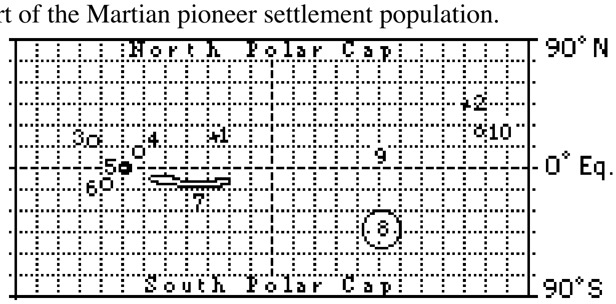


The Site for Mars' Main Settlement

by Peter Kokh with Bryce Walden

Pavonis Mons' Economic Importance as a Launch Site

In MMM # 18 SEP '88 pp. 6-7 "PAVONIS MONS: Very possibly the most strategic mountain in the Solar System" [republished in MMM Classic #2], we (Kokh) made the point that the combination of Pavonis' great height and its position astride Mars' equator destined it to play a major continuing role in the development of any Human Martian frontier. First its west slope could host a launch track, one far better advantaged than any up remotely similar candidate mountains on Earth: Mt. Cayambe in Ecuador, Mt. Cameroon and Mt. Kenya in Africa, Mt. Kinabalu in NE Borneo. The gentle slope of Pavonis reaches at least three times higher than any of these. Nor are there the torrential west slope rains that plague all the Earth sites mentioned. Add in the lower gravity that must be overcome, with an escape velocity 38% that of Earth's, and the West Pavonis Launch Track (WPLT) promises to be the export workhorse of the Martian economy. Since once such a launch track is installed, it will make no sense to export from Mars from any other site, Pavonis is likely to be central to a major part of the Martian pioneer settlement population.



A Mercator Projection of MARS with grid lines 15° apart.

KEY: 1-2 the two Viking landing sites; 3 Olympus Mons; 4-5-6 the three great Tharsis Ridge shield volcanoes: 4 Ascraeus, **5 Pavonis**, 6 Arsia; 7 the Valles Marineris; 8 Hellas basin; 8 Syrtis Major plain; 10 Elysium Mons

While thanks to its tenuous atmosphere which permits aerobraking, it actually requires less fuel to soft land the same payload on Mars as it does on the Moon, Mars is behind the economic eight ball when it comes to exports *with which to pay for* imports. Volatiles (methane and ammonia, containing precious hydrogen, carbon, and nitrogen; other HCN feedstocks) shipped to the Moon, LEO, and Space Settlements from its moonlets Phobos and Deimos are Mars' one real salable asset. Any manufactures made in the Martian Settlements themselves and intended for export, will either have to be something of very unique value made nowhere else, or find a way to compete on price via dirt cheap launch, i.e. up the *"Pavotrak"*.

(Someday, *if* Deimos can be "nudged" just 1900 miles closer to Mars into a synchronous orbit above Pavonis, and *if* Phobos' orbit can be moved out just 271 miles to cycle three times a Mars day exactly, and given just a little inclination with non-precessing nodes (much the bigger trick), then a Pavonis-Deimos Elevator could be built spanning a distance only 4/9ths as great against a gravity load only 3/8ths as great as a similar elevator on Earth, thus requiring much less exotic materials.)

Pavonis Mons as a Major Settlement Site

What we say here holds true of the other great shield volcanoes on Mars: Olympus, Ascraeus, Arsia, Elysium, etc. But Pavonis' equatorial advantage gives it an enormous edge.

In the previous MMM article sited above, we had also pointed out that the basaltic Pavonian slopes would allow us to build shelter with materials and methods with which we would already be familiar from our lunar experience. It is right here, on the topic of settlement construction, that we want to look at Pavonis again, and speculate about the "annexation" of this site into the Human-Gaian Diasporal reach.

Enter into play another trump card. Shield volcanoes, like Earth's largest, the Hawaii Big Island Mauna Loa - Mauna Kea complex, are built up of layer upon layer of relatively "runny" (melted tar-like) broad sheets of extremely fluid lava of low silica and gas content and very high temperature (1100°C = 2000°F). This is what gives shield volcanoes their gentle slopes in the 3-5° range (as opposed to the more photogenic classical cone shaped volcanoes like Fuji). Part of the process by which these layers are laid down results in the formation of numerous lavatube conduits. The Big Island is "laced" with them, with 482 now listed and more being formed in each eruption. In the continental U.S. the Medicine Lake Volcano in northern California is another well-studied example.

Ronald Greeley, in his paper "Lava Tubes in the Solar System" (in G. Thomas Rea, Ed., 6th International Symposium on Vulcanospeleology, National Speleological Society, 1992) proposes lavatubes on Mars. In high-resolution images from the Viking Orbiter spacecraft, open channels and roofed channel segments are clearly visible as radial patterns around the summit caldera of Hecates Tholus, a shield volcano more than 200 km across, for example.

"Many of the lava flows that built both the shield volcanoes and the plains [of the Tharsis Ridge] were emplaced through lavatubes and channels. Some volcanoes such as Alba Patera, are enormous structures covering thousands of square kilometers and are composed of individual lava flows fed through extensive tube and channel systems" (p. 226). Greeley does not single out Pavonis Mons. He also says While lunar basalt is enriched in titanium, *some Mars basalts may be komititic flows,* "*magnesium-rich*."

To judge by the cross-section of lunar sinuous rilles which are collapsed lava tubes, lunar tubes are very much larger than those we have found on Earth, perhaps 50-100 times as high and wide and long. This may be due in part to chemical differences in the lava but probably has more to do with both the great volumes and depths of the sheets and with the much lower 1/6th gravity. We might expect Martian lava-tubes (gravity 3/8ths Earth standard) to be of intermediate size. Caverns tens of kilometers long and tens of meters wide would be very handy ready-shielded volumes indeed within which to place residential, commercial, industrial and agricultural areas of a major settlement complex.

Unless and until proven differently by a ground expedition, the expectation should be that Pavonis is honeycombed with many thousands of miles of lavatubes. In addition, we can conjecture about the chemical composition of the host terrain on much more solid grounds than we can about other sites on Mars. Therefore we can also plan *now*, a suite of building materials industries based on local resources.

[I had put the question to my friends Bryce Walden and Cheryl York of Oregon L5 (members of the National Speleological Society, the other NSS, and the principals behind the Oregon Moonbase effort in a natural lavatube, outside Bend, of which they game me a royal tour in July of '92.) "What percentage of the volume of a typical shield volcano is void, i.e. lavatube? That is, how large a ready laid out metroplex area might we find within Pavonis?"

Bryce sent back by email a veritable treatise on the subject, carrying his calculations, based on the Medicine Lake example, through some 58 equation steps! All the other sources cited in this article are contributed directly or indirectly by Bryce.]

The Argument from Medicine Lake (Bryce Walden)

Rogers and Rice, in "Geology and Mineralogy of Lava Tube Caves At Medicine Lake Volcano, California, give "over 300 caves" ranging from "short grottos under ten meters long to braided systems nearly ten kilometers long. Passage sizes range from 0.25-meter high crawlways a meter wide to 'dirigible passages' up to 25 meters in diameter." According to the authors, these caves represent 18% of the total lava tube volume originally formed (the others collapsed or were filled; that number is mostly derived from collapse trenches).

Medicine Lake is "a large shield over 33 kilometers in diameter which attains an elevation of 2,417 meters." Interestingly, lavatubes appear to form "in a zone on both the northern and southern flanks at approximately 1,370 meters in elevation ... with 1,250 meters taken to represent the base altitude of the volcano, leaving a net height of the volcano of 1,167 meters.

The average of the cave sizes quoted above is 5 km long with a diameter of 12.75 meter. We (Walden) estimate the actual average cave would be more like 1 km long with a 5 meter diameter. This is the approximate size of each major side of Young's Cave at the Oregon Moonbase, and comparable in size to many caves in Lava Beds National Monument. This yields a volume of a cave cylinder of 19,635 cubic meters per cave or 0.0000196 km^3 or a total of 0.00589 km^3 of "known" voids for the whole volcano.

Next, we calculate the volume of the volcano to be 332.7 km^3, consisting of an upper "shell" volume of about 37.59 km^3 including the 150 feet (45.72 m) nearest the surface from which all our evidence is taken, and a 295 km^3 "core volume" remnant, to which the argument might be extended.

Of the older caves deeper in the mountain, many will have collapsed or otherwise filled in over time, so this quotient won't hold for the whole volcano. If we estimate the core volcano originally did have a similar void quotient but has been 85% filled in by erosion, collapse, or subsequent flows (Cheryl York thinks this may be pessimistic, perhaps only 50% have been filled, but agrees with using this conservative figure at present), then the void quotient of the core would be 0.00235% and a net void figure for the mountain 0.0128 km^3. Please note this is about 13 million cubic meters of void in one small shield volcano. In sum, we might project 0.00386% of the Medicine Lake shield volcano volume is lavatube void with nearly 2 caves per cubic kilometer.

Extending the Argument to Pavonis on Mars

Now Pavonis Mons has a volume 700-1000 times larger than Medicine Lake. (Pavonis is 7 times the diameter of Medicine Lake, covering 50 times the area and is perhaps 15-20 times taller). Taking the smaller figure and extending the same argument, we might expect 10 billion cubic meters involving wider, higher, longer caves spaced further apart. If we postulate an average Martian tube interior ceiling height of 30 meters, that gives us a floor space of about 150 million square meters = 333 square kilometers = 128 square miles, the size of an American central city in the 1,000,000 population range - in a host mountain with a footprint of 40-45,000 square miles, bigger than Iceland and comparable to the size of states like Ohio, Kentucky, Tennessee, Virginia, Mississippi, Louisiana, or New York. (For comparison some other American states in thousands of sq. mi. are: CO 104, OR 96, MN 80, WI 55.)

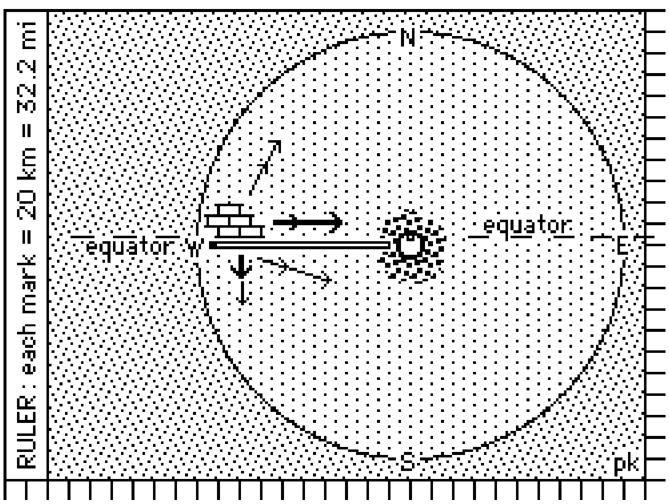
Pavonis (genitive form of Pavo, Latin for Peacock) covers an area about twice that of the BosWash Megapolis with its 40 million people. Since the lavatubes are not cheek by jowl, the potential population of the Peacock Metroplex will be significantly smaller than that. Add in the fact that it has to include within this shielded area support agricultural areas that will perhaps occupy the major fraction of available space (unless this function is taken care of in surface greenhouses - bear in mind that glass protects against UV damage and only seed corn need be protected from radiation.) We still come up with a ready to build-within protected area that can be home someday to tens, perhaps hundreds of thousands of Terro-Martians. As the economy expands to include similar satellite communities in other "Montes" shield volcanoes like Olympus, Ascraeus, Arsia, Elysium, etc., the valcano-hosted urban population of Mars could soar into the millions.

Because these pre-excavated areas are so spread out along the surface of these enormous volcanoes, they are likely to be incorporated as a number of separate communities representing individual tubes or convenient clusters of tubes, all sharing some Metroplex functions in common. We'll find names like Pavo Heights West, Pavo Cliffs, Caldera Crest, Rim Town, North Peahen, and many others whose names make no reference to the host site at all.

In addition, of course, there will be a scattering of "conventional" surface-trenched towns plying the mineral and other pluses of various sites. We'll have a better idea of where such specially advantaged spots might be after future robotic missions complete geochemical and altimetric maps of Mars.

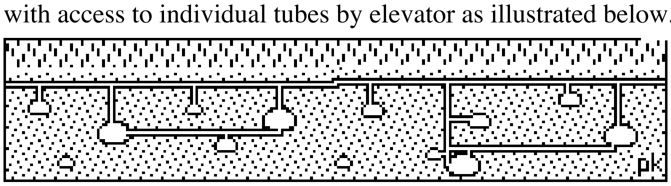
The Pavonis Metroplex Zone

So how might the Peacock Metroplex take shape? We could expect the initial settlement areas to hug the lower end of the Pavotrak launch track complex site and expand as the economy grows and demand arises along the track and around the mountain. Development might leapfrog areas in which lavatubes are relatively sparse or widely spaced to areas where they may be clustered. Some locations might offer enhanced concentrations of volcanic minerals. Sites near the caldera rim may support tourist activity.



Plan of the Pavonis Mons Metroplex Area: The lavatube-riddled shield volcano slopes cover an area about 250 mi. in diameter. The corridor for the launch track up the west face of this equator-straddling mountain is shown, along with the site for a Pavonis-Deimos Elevator Base in the caldera summit. The suggested site for the first settlement is indicated by the brick-pattern area with arrows showing logical directions of early metroplex expansion. Eventually, the entire base of the mountain could be occupied, attaining a population of up to a million citizens or more.

The lavatubes being arranged more or less radially away from the summit, locally they will be arrayed more or less in parallel. Those nearest the surface will be the first to be exploited. This suggests that pressurized cross-connecting roads might best be trenched into the mountain slope surface with access to individual tubes by elevator as illustrated below.



Schema of lavatube habitat areas and their pressurized connectors. (Shown: cross-section of mountain slope perpendicular to radius) Dashes at top indicate mountain slope surface and direction of the summit. Principal "cross-connectors" are most logically trenched and covered at the surface, with access to individual lava tubes by elevator banks. Cross-tunneling only makes sense between major close neighbor tubes and tube systems. Some lavatubes will be "off the beaten path" and by-passed in creation of the Metroplex.

Freight and Passenger traffic are likely to be separated especially in elevators. As to solar access, it will be possible, and more efficient in the long run to pipe in sunlight by mirrored shafts or fiber optic bundles than to use surface-available solar power (just 36-52% as intense as at Earth, depending on the time of Martian year) to produce artificial lighting tied to the sunrise-sunset period above. We might see both, with nearer-surface tubes trying direct access, deeper tubes opting to repeat surface lighting electrically. Either way, it will be more cost effective to faithfully follow the seasonally varying length of daylight than to produce a standardized day-night cycle below.

Pressurizing leaky lunar lavatubes won't be smart. On Mars where we *want* to alter the given atmosphere over time, we might do just that. Pavonis Mons will be one of the most interesting settlement scenes in the entire Solar System. ***PK***

By Peter Kokh

[A followup on the piece "CANALS on Mars: from self-deception to reality", in MMM # 62, FEB '93 pages 6-7.]
[Republished in MMM Classics #7]

Lowell's List

Almost all science fiction novels about Mars written prior to the successful Mariner 4 and 9 missions, took the existence of the canals "observed" by Sciaparelli, Lowell, and others as a given. Either they were dust- and weed-choked ruins of a long-vanished native Martian civilization or still working water routes maintained by a handful of native survivors. And these writers gave them names from Lowell's List.

We now know such features to be illusory. Yet it is possible that future Martians tracing ancestry back to Earth will someday build canal-like aquifers to transport water across Mars. These settlers can either choose to start afresh, naming them after prominent natural features along the route - or after the mistress of the construction team boss. But they could just as easily choose to exonerate Lowell's List, thereby infusing the romance of a tradition that predates by several decades the dawn of the Martian Era (1/1/1961 = 1 Gemini 1 m.e.).

Two readers responded to my request for sources of information on the names Lowell and others had given to the lines they honestly thought they were observing. Jeff Sanburg (Skokie IL) wrote that 1908 vintage maps of Lowell's canals are to be found in Willy Ley's classic Mariner IV to Mars. Francis Graham (East Liverpool OH) sent us the complete list, an astonishing 183 names in all. Our thanks to both!

Of these 183, 89 had been "observed" less than ten times. Another 61 had been recorded less than 33 times. That leaves 33 names given to linear phenomena "seen" from 33 to 127 times each. Agathodaemon is the one observed and drawn most frequently. "Earning credit" towards immortalization as names of future human-engineered Martian aqueducts, they are:

Agathodaemon 127	Ambrosia 36	Araxes 93
Bathys 69	Brontes 38	Cambyses 34
Cephisus 35	Cerberus 44	Coprates 41
Corax 33	Daemon 118	Eosphorus 56
Eumenides 103	Euphrates 36	Ganges 82
Gigas 60	Gorgon 33	Hebe 37
Jamuna 39	Laestrygon 41	Nectar 87
Oceanus 37	Orcus 35	Orontes 33
Phison 56	Pyriphlegethon 53	Sirenius 60
Steropes 46	Tartarus 42	Titan 38
Tithonius 78	Typhon 33	Ulysses 33

Alternately, these canal names are available for water-tanker truck routes from the poles to the equatorial regions, even for the trucking firms so involved. ***PK***

MARSCALENDAR

pk

A Tale of Two Calendars

"A Calendar for Mars" by Robert Zubrin
Ad Astra, November/December 1993, pp. 25-7

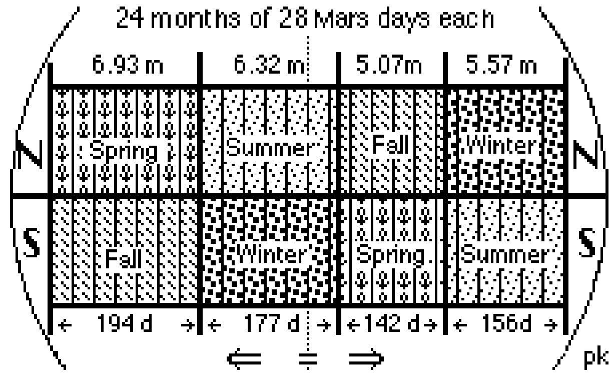
"Mars Calendar" by Peter Kokh
Moon Miners' Manifesto # 19, Oct. 1988, pp. 5-6

Report and Comment by Peter Kokh

Let me begin by saying that I *endorse* Bob Zubrin's Mars Calendar design - with two minor reservations - even though there are aspects of my previous suggestion that *in the abstract* I might prefer. *In the concrete*, Zubrin alone has the name recognition and prestige needed to gain widespread acceptance, perhaps even official adoption, for such a proposal. That would be a coup in the effort to raise public awareness of Mars and of its similarities and contrasts to Earth. These days, Zubrin, as much as anyone, is Mr. Mars.

In the calendar proposal outlined in my earlier article, I began with the goal of preserving the 365-day *like* rotation of holidays and anniversaries with which we are all familiar and comfortable. Mars' orbital period is some 669 Mars days long (690 Earth days), a long period almost commensurate with 2 Earth years (730.5 d). So I thought to divide it into two equal "versaries" (coined from anniversary) of 334.5 Mars days each - per "Zodian", one complete orbit, i.e. pass around the Zodiac. The logical point of division would be not along seasonal lines but between the in-leg (from aphelion, when Mars is furthest from the Sun, to perihelion, when Mars is closest to the Sun) and the out-leg (perihelion back to aphelion) portions of Mars' orbit. While such a duplex calendar would not neatly coincide with the Martian seasons, neither does the common Earth calendar. Earth's year begins not with the first day of spring, which Zubrin's proposal assumes to be the logical point, but at perihelion, on January 1st when Earth is closest to the Sun. (It is cold in the northern hemisphere while we are actually at our closest to the Sun because of the 'overruling' axial tilt of Earth's north pole away from the Sun at that time.)

Next I sought to honor the 28-30 day "monthly" cadence with which we are equally at ease. This means, of course, that when months begin and end can have no neat relationship to the arrival of seasons on Mars. But neither is any such neat relationship marked in our own calendar.



The 28 date months I had proposed would rationalize the traditional 7-day week, the most change resistant temporal rhythm in all human experience. Every month could begin on the same day of the week, *that year*. As the paired 334-, 335-date versaries called for would be together 4 dates longer than 95 weeks, a "Sunday" versary pair (or Mars year) would be followed by Thursday, Monday, Friday, Tuesday, Saturday, and Wednesday years (or by whatever other names the weekdays on Mars might one day be called) in an ever repeating cycle. However, day-date coupling *could* be arranged by placing an eighth "leap day" at the start of each season.

Zubrin's calendar begins the year with the first day of northern Spring (southern Fall). (Historically, Earth's calendar *used to* begin with March - December means literally the 10th month, not the 12th!). With three 'months' per season and 12 per Martian year, it becomes logical to denote them by the zodiacal constellations in which the Sun appears from Mars. [Ed: let's not call them "months", an inappropriate allusion to the Moon, but "**zodes**" ("sign" has a bad connotation).]

The advantage is obvious. Almost everyone, space aware or not (indeed especially the space-ignorant!) already knows the names of all twelve Martian months or zodes!:

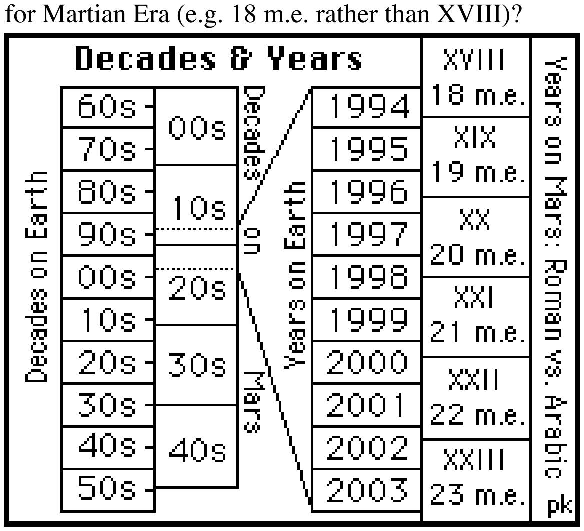
Gemini, Cancer, Leo, Virgo, Libra, Scorpius,
Sagittarius, Capricorn, Aquarius, Pisces, Aries, Taurus

Choosing to enshrine these names into Mars' Calendar will at least superficially lower the threshold of comprehensibility of our dream of settling Mars for the average person on the street. That should not be dismissed as a spurious consideration, if we want someday to *realize* that dream. With the right publicity campaign, more and more people on hearing the name of some zodiacal constellation, will think Mars, not astrological sign.

In the Zubrin proposal, with the months or zodes varying in length from 46 to 66 Martian days or sols (the seasons varying so much in length because of Mars eccentric orbit - its angular motion much faster when nearest the Sun than when farthest) no easy weekday repeat pattern is likely. But again, overall day-date coupling could be arranged by four out-of-week days, perhaps beginning each season: Gemini 1, Virgo 1, Sagittarius 1, and Pisces 1. But Zubrin himself does not discuss the day-date question in his proposal. Perhaps future Martians *might* decide the disorder of our present uncoupled day-date system provides healthy variety. (But is it the wisest choice to thus pacify the eternally warring Friday, Saturday, and Sunday clans of fundamentalism?)

One of the most spirit-lifting appeals of opening new worlds like the Moon, Mars, and Space Settlements is just this opportunity to start over "afresh", to shed the more irrational baggage of history, and choose our cultural infrastructure more wisely, so that the pace of our lives might be more in harmony with the grain of nature. The unaddressed day-date question aside, Zubrin's proposal is a brave attempt to do just this. The 46-66 date long zodiacal months calibrated to Mars' eccentric season patterns and the 88% longer Martian year must establish a new, characteristically Martian feel for time, something that will echo throughout Martian culture. His calendar showcases what is so transcendingly different about Mars, providing an appropriate hanging strip upon which to time-fasten other cultural innovations: holidays, feasts, and rites of passage etc.

On the other hand, Zubrin proposes using Roman numerals to keep track of Martian years, beginning with year I starting when Gemini 1 (on Mars) last coincided with January 1 on Earth in 1961. This *is* a good choice for beginning the Martian Era as it is near the outset of the Space Age and the first probes sent towards Mars, i.e. when human activity near/at/on Mars began. My point is that the unnecessary choice of Roman numerals, hesitatingly familiar to many, raises an instant barrier of incomprehensibility for many others. Would Dr. Zubrin accept a friendly amendment and use the much more familiar Arabic numerals, perhaps following them with m.e. for Martian Era (e.g. 18 m.e. rather than XVIII)?



Another, equally *nonessential* point of this proposal evoking grave misgivings is that it *chooses* to redefine not just the day and hour on Mars, making them all longer than our familiar periods by a constant factor of 1.0275 (Mars' day 37-some minutes longer than ours) but *also* the minute and the second. This would mean that *no* science textbooks used on Earth could be used *as is* on Mars. But we do not have to use analog clocks. It should be no big deal to devise digital clocks for Mars that incorporate the longer hour and day, but that use the standard second and minute. The Mars' hour would simply advance by one every 61.65 *standard* minutes of 60 *standard* seconds. So I submit this second and last friendly amendment.

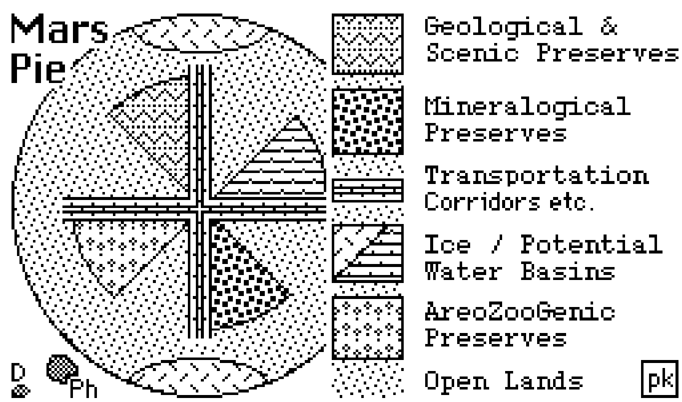
While anything done in advance on Earth can hardly be "binding" on future Martian settlers, adoption of this center-piece of cultural infrastructure would put into place a tradition-like momentum hard to set aside. The settlers will have more urgent things with which to concern themselves. By adopting a really good Mars calendar *now* we can only help them.

Zubrin includes an "Areogator" to equate Earth dates and Mars dates. While cumbersome, the formula-chain could easily enough be reduced to run with the press of a single function key on a specially designed calculator. Might not the Planetary Society, best positioned to market such a device, contract with a manufacturer to make such a product, thereby increasing the extent and depth of Mars awareness?

Bob's contacts with the Planetary Society are a plus here. If TPS does adopts the Calendar, if ***Ad Astra*** adopts it (it appears that they are so inclined), if science fiction writers adopt it, and if NASA-Russian Mars Mission planners do so - then I think it will prove to be a done deal. Engage! **PK**

The MARS HERITAGE Zoning Resolution of 20 m.e./1997 a.d.

A Proposal to The Case For Mars VI Conference to be held in Boulder, Colorado, July 1996.



Forward

In MMM # 62 FEB '93 "Federal Republic of MARS" p. 5, we spoke of the need for very early home rule for Mars (it's beyond the short range distances within which "umbilical" connections are logistically feasible) and mentioned the logic of setting up a regime of federal reserves to protect the major geological and scenic areas, major known mineral deposits, major known deposits of ice (and possibly of permafrost as well), and the two moonlets: Phobos and Deimos. This would leave the balance of Mars open to settlement and commercial resource development - under the rule of law, of course - while protecting a/the major portion of the planet's special heritage for future generations of human Martians.

National Parks and Monuments

The Geological and Scenic Areas to be preserved as National Geological and/or Scenic Parks and Monuments could be restricted to those treasures identifiable as such from pre-human exploration missions (Mariner, Viking, MESUR, etc.) Other similar treasure spots identified after the era of human visitation has begun, might be put on a list of places which state or provincial or local governments must protect according to set standards. This would be similar to the setup in this country where not all geological and scenic wonders are part of the National Park, Monument, or Forest systems, leaving many undisputed gems within State Park and Forest lands.

There should be provision within the law for future tourist village/center enclaves in such protected areas wherever a tourist market would otherwise arise. On this list would be the great shield volcanoes Olympus, Arsia, and Ascraeus (with Pavonis Mons being a likely major exception - see the article pp. 3ff.); the great Valles Marineris system of canyonlands, and other places of lesser present fame.

National Mineral Endowment Reserves

Currently, we know little of a non-general nature about Mars' mineral endowment and much less about how any such resources are distributed over the face of the globe. It is possibly that future robotic orbiters equipped with gamma ray spectrometers and capable of generating multi-spectral thematic maps will replace current ill-constrained conjecture with knowledge sufficient to trace the outlines of the planet's "Economic Geography" to the point where we can generate a short list of sites well suited for local resource-dependent settlement.

At the same time, without follow-up "ground truth" missions to check out percentages, quality, feasibility of extraction, and other salient make-or-break details, we may not be able to further trim the list for Settlement Site #1. Meanwhile, other considerations may motivate an earlier decision such as proximity to major geological sites, or to logical surface transportation corridors, or to other potential sites (site clustering).

While obviously, settlements must have real access to mineral resources, uncontrolled there-is-no-tomorrow extraction can be avoided by federal ownership of the major pre-detected deposits coupled with a system of licensed extraction and settle-ment "enclaves". In the absence of clues detectable from orbit, however, it will be difficult to protect more than a very small portion of Mars' mineral heritage in this way. But at the least, a regime can be put in place that can be extended to cover and husband other endowment-rich areas of the planet later on.

Potential Water Basins and River or Canal Routes

It is clear that the polar ice caps and at least some of their periphery should be within federal preserves. Permafrost areas are another thing. Future robotic orbital missions might possibly locate the major, nearer-surface frozen soil zones. A debate is in order whether any of these should be set-aside areas or not. Certainly there will be many smaller buried ice pockets that escape orbital detection, either because they are too small, their water content is economically marginal, or they lie too deep below the surface. These, at least, should be up for grabs.

But if someday we are to "terraform" Mars, or better and more naturally, "restore" or "rejuvenate" the planet to its previous more benign condition, then at least some low-lying areas are potential future lakes and seas. Our current altimetric knowledge of the planet is largely conjectured. Future planned missions will give us a map from which we can identify and rank potential catch-basins and even early "immature" water drainage routes. (Mars Observor would have done this.) As to the latter, a little bit of engineering here and there can prod hesitant drainage routes into more desirable paths. Even now, while the area of climate change on Mars is well beyond our horizon, we ought to be able to get enough of a handle on the possibilities to zone aside some areas as likely future basins and riverways, *making sure all early settlements are on "high ground"*. We don't need to repeat the stupidity of shore/flood-plain development that is so rampantly entrenched on Earth.

AreoZooGenic Reservations – AZGRs

Just as far off perhaps is the day when Mars' CO_2-rich atmosphere has thickened enough to permit drip-irrigated outdoor surface plantations of specially bioengineered "Mars hardy" trees and other plants. In advance of that day, it may soon be possible to identify favorable "fertile soil" areas, separate from other types of preserves, that might be at least partially protected as potential future National Forest lands, in so called AreoZooGenic Reservations, AZGRs (*Ares* is Greek for Mars).

Much more remote is the possibility of outdoor wild-life on Mars. Vegetation can handle a CO_2-rich, O_2-stingy atmosphere, if it is thick enough (perhaps ten times the present value on Mars of near a hundredth Earth normal). So the idea of setting aside areas, *other than* the AZGRs just mentioned, as "future Wildlife Refuges" has little merit and no urgency.

Air/Space/Surface Transport Hub/Corridor Preserves Land Grants to Infrastructure Concessioners

On Earth, at least in this nation's past, designation of railroad and highway corridors and associated land grants have played a major role in opening up the American West to settle-ment and in largely confining it within certain stripes and pockets. It may be wise to consider something similar for Mars. It will be difficult to plan anything logical along such lines, however, until we have a clearer idea of the likely modes of surface and point-to-point transport on Mars.

Air transport, even in the thin air of today's Mars, is a recognized possibility, especially with hydrogen bag buoyancy assist. Airport areas both for VTOL vehicles and those needing *very* long runways are logical set-asides in potential settlement areas offering major identifiable assets or advantages.

What about highways? What about Mag-lev or other railway routes? Given the altimetric data that should be forth-coming from already budgeted missions, it should be possible to identify a logical circum-planetary near-equatorial surface route, and even the major local route options ("the Polodona", to borrow E.R. Burroughs' name for Barsoom's equator). Logical spurs to other interesting or economically promising temperate or arctic areas could also be "designated". Where the route offers wide leeway, protection need be of only the most general kind. But where it is constricted, e.g. mountain passes, or narrow valleys, specific land reservations may be in order.

Federal and Provincial Open Lands

Settlement sites and even old-fashioned individual and communal homesteading might be liberally permitted outside the Federal Land Reserves suggested above. Permits, of course, ought to be granted on the basis of some minimum set of demonstrated assets and capabilities lest the Mars Republic wind up with a lot of mini-communes on the public dole. Make no mistake about it, atmosphere, ice, and permafrost notwithstanding, Mars will be *only slightly less harsh a mistress* than the Moon. Until some far off age of planet-wide climactic engineering, each community or isolated homestead will have to subsist outside the context of a given all-cradling biosphere, having instead to provide a minibiosphere of its own.

Prime sites for settlements engaged in mining and manufacturing and/or tourism are along the boundaries of the geological, mineralogical, scenic, ice/permafrost, and transport corridor reserves. (Tourism is likely to be a rather low income earner for a long time to come - until either Mars' population has reached some critical mass, or Earth-Mars passenger transport costs and times have fallen some orders of magnitude.)

If state or province boundaries must, by prior law, be established insofar as feasible to follow potential watershed *divides* (*not* potential river courses which only balkanize such watersheds!), there will be put in place *a complementary tool* to help serve shared environmental interests and responsibility. All these features, outlined above, can be adopted within the next decade or two, prior to the first human visits to Mars. The settlers do not need the pain and tribulation of a "Wild, Wild, Lawless Frontier" - they will have hard enough a time without all of that. Suitable amendments can come later. ***PK***

MMM #74 - APR 1994

* [modified house clip art courtesy Hypercard™]

When settlers finally get to "settle in" on the Moon, moving out of the sardine can and into habitats built of local materials, their new "homes" will be quite different from anything we are used to. Yet the new abodes will fill the same basic needs. This month, MMM begins a new series. We open with some "prerequisites" for lunar architecture 101. How will we provide Visual, Solar, and Utility Service Access? — below

Introducing a NEW MMM Article Series

Many a novel has been written set on the Moon. Yet the reader never gets an idea of what a lunar home might, or could be like. Had the scene been anywhere on Earth, these authors would have dropped plenty of descriptive mood-setting details. But here, where none of them seems to have a clue, they leave not just some things, but everything to the imagination. Even Heinlein in his "The Moon is a Harsh Mistress" speaks only vaguely of the city and its underground "warrens".

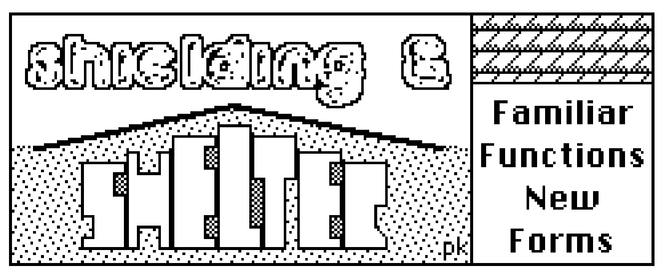
Those who have only NASA achievements and plans as a guide are neither better nor worse off. The teacher we must turn to is neither any one of the science fiction writers, not even all of them pooling their collected insights, nor NASA-aerospace metal-bending engineers - but the Moon itself.

What sort of shelter can future homesteaders create relying on local resources, fashioned, constructed, finished, and decorated in local conditions? As on Earth, the constraints imposed by the suite of available materials do not dictate everything. There will be room and plenty of it, for architects, craftsmen, and artists to create ever new expressions of form, function, comfort, harmony, utility, and beauty. We might predict that in a world with steep economic disincentives to import from the endless diversity of wares and wears of Bazaar Earth, the role of local architects, craftsmen, and artists in providing distinctive and personal expressions from a limited but slowly growing number of choices will be much prized.

Some things will be the same. People need space: private space to mold in expressing their own personalities and into which to retreat; and communal space in which to be comfortable together. Sardine cans won't do. Indeed, against the stark sterile barrens outlocks, we'll need even more structured per capita space for real comfort than do modern Americans.

Other things will be different. With no transcending natural biosphere as a cradle, homesteading as we have known it will be orders of magnitude more difficult.

This month we talk about some of the features we'll want to insist upon. Next month we turn to the architectural possibilities for Made on Luna modular housing. After that, we'll discuss how lunar home interiors can be decorated and furnished, and the role they'll play in settlers' lives.



READINGS From Back Issues:
[Republished in MMM Classics #1]
MMM # 1 DEC '86 p. 2. "M is for MOLE".
MMM # 5 MAY '87 p. "Weather?"
[Republished in MMM Classics #4]
MMM # 37 JUL '90 pp. 3-5. "Ramadas," "Flare Sheds".
[Republished in MMM Classics #6]
MMM # 55 MAY '92 p. 7. "Moon Roofs".

by Peter Kokh

On Earth, "Roof" and "Shelter" are synonymous. The roof (along with the walls, doors, and *wind*ows) protects those underneath (within) from the wind and rain and other discomforting atmospheric phenomena. A well designed roof is also a major part of the home's temperature modulation apparatus. And always to the builder and/or architect if not always to the homebuyer (almost never the renter), the arbitrary aspects of the roof's design are key to the style of the home as a whole.

We go through life mostly unaware and unappreciative of the fact that some of the ways in which we are "sheltered" are "given", provided in common for all without our need to be concerned (until recently) by the Earth's warm moist blanket of breath-giving air. The atmosphere "shields" us from most cosmic rays, most ultraviolet light, most solar flares, and most meteorites. And it works with the oceans to greatly moderate the much greater temperature extremes to which we would otherwise be subject.

On the Moon, we will have to provide for ourselves both shelter and shielding. The pressure hull of the individual habitat, or of a shared megastructure, will be something new, keeping atmosphere and moisture captive *within* - something we have never had to do before (at least until the dawn of air conditioning and more recently of determined thermal conservation). Atmosphere and hydrosphere recycling functions must be brought indoors in the process.

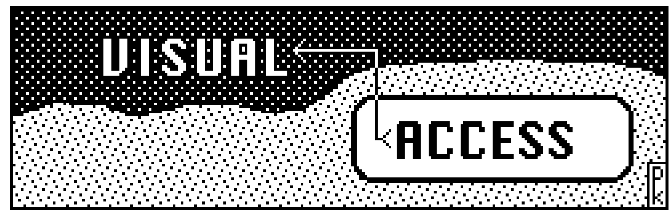
Those storms left outside, just outside, are those left miles above on Earth. To do this, we have to provide the equivalent of miles of atmosphere in a condensed solid or liquid form. Fortunately, the loose lunar regolith soils or Moon Dust that blankets everything 2-10 meters (yards) thick will do the trick quite nicely. So we can think of this shielding overburden as a solidified atmosphere - at least in this respect.

Unless the lunar home lies within the shared lee space of a common shielded megastructure, it must provide both shelter and shielding. The hostility of the universe at large will be held much more closely and fragilely at bay. A lunar home will be refuges in a much more intense and dedicated way than any terrestrial one. Surface temperature extremes are a case in point. Fortunately, lunar regolith used as shielding is an ideal moderator. A couple of meters down, the ambient temperature does not vary by more than 3 degrees Celsius all year, being highest in March, lagging perihelion in early January, lowest in September, lagging aphelion in early July.

Locally derived shielding can be provided in several forms. Loose regolith can be spread, dumped, blown, or bulldozed over the top and side banks of the structure(s) to be protected. Or the same material can be poured into lunar fiberglass "sandbags" or sintered into igloo-making blocks and then put in place. For those who can afford shielding with an 11% exotic imported content, water made with local oxygen can provide shielding and translucency alike. All-lunar glass block may be a cheaper and thermally more forgiving way to provide the same effect over glass-top habitat hulls.

Earth's roofing professions hardly supplies expertise needed for the much bigger job on the Moon. Here, "Shielding Engineers & Contractors" will be among the most prestigious headings in the settlement `Yellow Pages`. Making their job more challenging will be the need to provide for easy shielding handling and removal when existing habitat space must be replaced, repaired, retrofitted, or modified externally, and even expanded with add-on additions. Their expertise will be needed also for retrofitting interior visual, solar, and added personal and utility access to the surface.

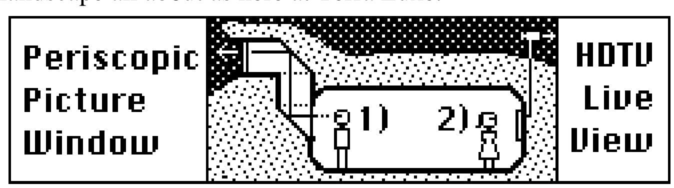
In short, a lunar home will have to take its refuge and safe haven providing function much more seriously and less casually than even its most thoughtful terrestrial counterpart. Home Sweet Home will be a sentiment more appreciatively felt than ever before.



***READINGS From Back Issues*:**
[Republished in MMM Classics #1]
MMM # 1 DEC '86 p 2. "M is for MOLE"
[Republished in MMM Classics #6]
MMM # 55 pp.**?** visual access (lunar skyscraper article)

by Peter Kokh

The one single event that got me most excited about the possibility of lunar settlement was an '85 personal tour of a unique "earth-sheltered" home called Terra Luxe (Earth Light) about 30 miles northwest of Milwaukee in the Kettle Moraine glacial relic area. Built by architect George Keller (German for cellar), Terra Luxe is unique in having no sun-exposed south façade. Yet despite an earthen overburden 8 ft. thick,the place was flooded with sunlight from mirrored shafts in the ceiling fed by sun-following mirrors. More to the point here, in every outside facing wall was a 4'x8' picture window out on to the picturesque countryside. This neat trick was accomplished by a pair of rectangular mirrors set at 45° angles in a vertical shaft - "periscopic picture windows" so to speak. To this date, I have never been in a house so refreshingly wide open to the landscape all about as here at Terra Luxe.

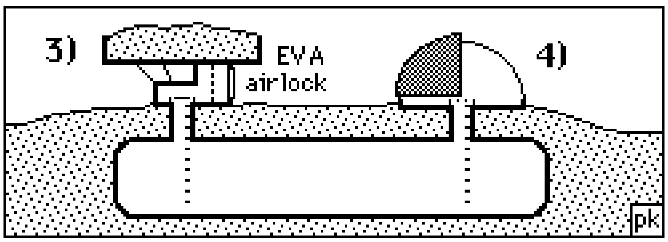


Could such a system for real visual access be in some way adapted to lunar conditions? Why not? The glass used could be reinforced with transparent glass fibers (in lieu of lamination with plastic, as we might do here) and be somewhat thicker - we would want to reduce the brilliance level anyway. Then there could be a pair of horizontal panes at the bottom and top of the vertical shaft (see dotted lines in sketch above) to allow the atmospheric pressure between them to be gradually stepped down to reduce the stress on any one pane, e.g. 0.25 ATM, 0.5 ATM, 0.75 ATM (or similar percentages of whatever the interior habitat pressure was set at). Finally, an easily replaced "sacrificial" glass composite meteorite shield can sit in front of the outermost pane of the sealed periscopic unit. The "Z-View" unit would preferentially have north or south exposures so as not to admit the rising or setting sun (unless equipped with automatic (hence failure-prone) shutter system. Meanwhile, the indirect visual path would preserve full line-of-sight shielding for the habitat occupants.

It would seem that such fixed units with no operating parts would be both strong enough and well enough protected to be built in genuinely "picture window sizes. These units could be standardized preassembled and tested modules made to be snap-installed in standardized habitat wall "rough openings".

Of course, there is the electronic solution of thin, hang-on-the wall ultra-high-definition television view screens ("you can't tell it from real" will go the hype) for those who dislike KISS (keep it simple, stupid!) solutions and who can trust that the signal received is coming in untampered, and live and that neither their "window sets" nor the surface telecams that feed them will ever break down and need costly repairs. I'd like to see both options pursued and predict that both will find ample market share in a growing settlement.

A third solution is the cupola observatory. Here direct views of the surface are afforded while maintaining a very limited sky exposure, thanks to the generous shielded eaves.



A fourth solution is the surface dome, with a clock - driven sun-following shade screen. This would open the view to the star spangled sky, and to Earth for homes on nearside. The penalty, of course, would be accumulated cosmic ray exposure and thus the need to budget time spent therein.

Perhaps some would expect visual access to be a neurotic need of the few unadjusted persons. Who needs to be reminded of the hostile life-threatening radiation-scorched surface when interior spaces can be made so comfortable and reassuring. But I suspect lunar settlers will come to appreciate the unique beauty of the magnificent desolation outlocks and enjoy monitoring whatever surface activity there is outside their safe underground homes. Providing real-time true vision exterior visual access to all will promote acculturation to the Moon and a healthier, more balanced morale. MMM

SUN MOODS

Letting in the glory and warmth of real Sunlight

By Peter Kokh

***READINGS From Back Issues*:**

[Republished in MMM Classics #1]
MMM # 1 DEC '86 p 2. "M is for MOLE"

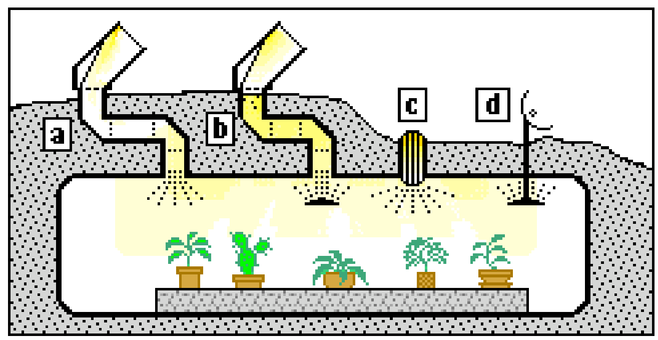
[Republished in MMM Classics #3]
MMM # 27 JUL '88 p. 5 "Ventures of the Rille People:
Pt. II Rille Architecture General Concepts.
D. Letting in the Sun"

[Republished in MMM Classics #5]
MMM # 43 MAR '91 p. 4. "Dayspan"

[Republished in MMM Classics #7]
MMM # 66 JUN '93 p. 7. "Let there be LIGHT"

On Earth we take sunshine for granted. Not that it's always there! Nor that we don't appreciate a nice sunny day! But the point is, we get to go outdoors and bask in it- at least once in a while. On the Moon, the Sun shines gloriously, free of even a wisp of cloud or haze, for fourteen and three quarters days at a time, before setting for as long. One hundred percent predictable. But! We can't go "outdoors" to enjoy the brilliance it confers on everything nor its warmth on our face or back - not without cumbersome space or pressure suits. Nor will it automatically flood in through simple windows.

Two things are clear. We will have to enjoy the Sun indoors, and we need its rays to bathe us and our living space from *above*. Living underground, or under 2-4 meters (yards) of lunar regolith shielding, one might expect that to be a neat trick. Not really. Sunlight can be captured by a Sun-tracking mirror or heliostat and then directed via a broken path (to preserve line-of-sight shielding) to various points along the ceiling (or walls, if deflected upwards). Such a pathway can have a number of intermediary sealed panes to step down the interior pressure, just as in the Z-View window system described in the piece above. Option a) below.

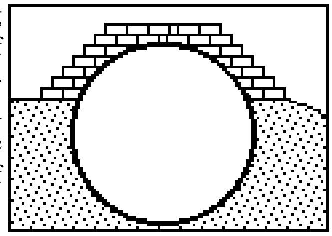


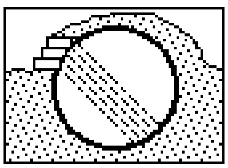
Option b) is similar but the light is deflected against the ceiling. Option c) uses a smaller diameter direct path filled with bundled glass fiber-optic strands in a sealing matrix. This also preserves shielding, substituting glass for dust. It could be coupled to a heliostat or not. The bundle can just as easily be branched to produce little pools of built-in spot and mood lighting at various places within the habitat. As such, it would be an important part of architectural decor and setting.

Option d) produces electricity from a solar unit at the surface and regenerate "sunlight" electrically within the habitat, faithfully repeating the visible spectrum distribution and intensity. Artificial sunlight does work! I have seen convincing "skylights" in the basement ceiling of a seven story office building. The light pools beneath them mimicked bright sunlight quite effectively. Over-illumination (compared to comfortable reading and task lighting) is as much a key as color fullness. So this option is a possibility where direct funneling of true sunlight is impractical: in lower floors, in lavatubes, and during nightspan. Actually, even where directly channeled sunlight is quite feasible, the natural and artificial systems can be combined, with artificial "sun lamps" on the surface feeding sunlight delivery systems during nightspan.

Over-illumination, is itself quite therapeutic, flooding interior spaces with all the light you'd experience in the middle of a Kansas cornfield on a late June noon under a cloudless sky. Such intense lighting can be applied in garden areas, for example; or in a private meditation chapel, or public church, filtered through stained glass art panes.

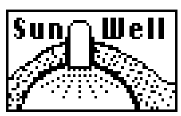
So far, we have only spoken of ways to bring the sunlight into the interior of hard-hulled regolith-shielded habitat spaces. But the upper portion of a habitat module can be made of translucent glass composite, with the shielding provided by glass blocks. That much glass would cut down on the amount of light being transmitted appreciably. But if desired, this loss could be compensated by reflecting several suns' worth of light upon the outer surface with the aid of peripheral mirrors.



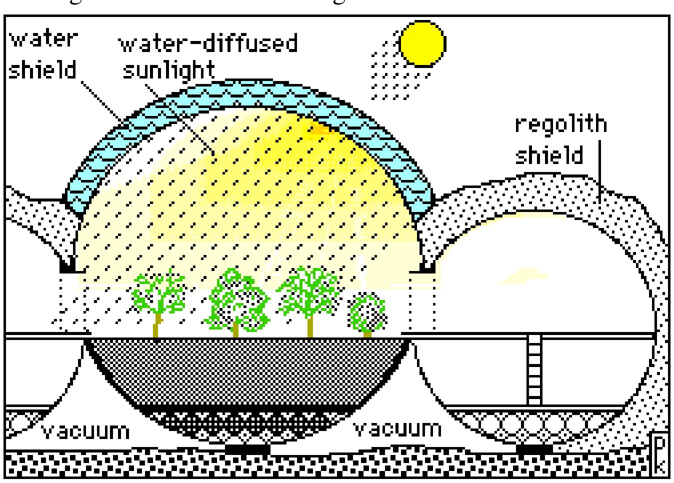


A combination of conventional and glass block shielding is a more modest possibility; for example, a clerestory of glass block used on the sun-facing bank of a structure running east-west.

Finally, liquids also provide both shielding and translucency. We have to have stored reserves of water at any rate, and storing it overhead as translucent shielding is a Marshall Savage suggestion that deserves attention. This combo fresnel lens bottom water skylight - solar hot-water tank is our own idea.



A more ambitious project is to use water shielding over a glass-domed or -vaulted garden-atrium or farm module.



In "The Millennial Project", p. 209, Savage suggests circulating the water through cooling tanks to keep the water shield under thermal control. More on this another time. MMM

"The excellent engineer knows when better is worse than good enough"

KGB drop-in Core

by Peter Kokh

No, this isn't an article about an unreformed cadre of commie secret police dropping in unexpected and unwanted to harass peaceable lunar settlers in their homes. Rather by "KGB" we mean Kitchen, Garden, Bath (& Laundry). "Drop in Core" (~~corps~~) means a standardized preassembled combination plumbing, air circulation, and electrical and communications service entry package needed to make a modular pressurizable architectural shell into a habitable home. *Just add* furniture, furnishings and people - those very things that personalize and customize each dwelling beyond initial floor plan choice.

The point is that on the frontier, on any frontier, there is a severe labor shortage. When you're pioneering a settle-ment from scratch, there's always far too much to do for far too few people. Labor-saving measures are vitally essential, especially in all the steps necessary to bring a new structure to the point that it can be occupied. It will be imperative to do this as fast as possible, in a couple of days per housing unit perhaps. Once inside, the new residents can take their blessed time "finishing" their new abode, personalizing it to taste.

That is the stage where labor-intensive options are appropriate - and not before. And in the early years, such work will be done "after hours". For every 'able-bodied' person available will at first have to primarily employed in the manufacture of exportable items, in settlement maintenance chores (biospherics, air/water systems, food-production) or in bare-bones settlement expansion as we've just described. (Almost all the paper-pushing jobs will be electronically farmed out to support personnel on Earth, far cheaper to support).

Drop-in plumbing cores have long been one of the more common tricks of Manufactured Housing, prefabricated in an automatable factory assembly line in controlled quality conditions with major savings both in labor-hours and labor-rates. The idea is not new. I first came across it in the mid-sixties when Israeli architect Moshe Safde was planning his still stunning contribution to Expo '67 in Montreal. Habitat '67, still standing and occupied as Cité du Havre. If you've never seen it and ever get to Montreal, this mind-expanding complex is worth the side trip. But it may well be that other innovative builders had used the idea previously.

Lunan KGB Cores contain the water supply, drainage connections, fresh air entry, stale air exit, preliminary water/ air treatment and thermal control equipment, electrical service entry master panel, communications service entrance, etc. All these things can be put together in compact standardized form within a wall or two at a factory then delivered to the job site for EZ installation without subcontractors. The kitchen sink will share a wall with the bathroom shower/tub, toilet, and lavatory. Despite such standardization, there will still be a lot of leeway in selection and arrangement of fixtures, appliances, and decor. The connections made in a factory setting can meet higher quality standards. Saliently, total labor hours as well as expensive subcontractor work at the job-site are much reduced.

An effect of the use of drop-in cores is to cluster all the utility service connections and entrances in one spot in the house - not the case in most onsite construction! Thus it makes sense to locate our KGB unit by the 'street' or 'service alley' entrance of the home, along which ever access corridor where ever the utility mains are laid. These constraints will still leave plenty of room for floor plan and home size variety.

We'll have to do some rethinking, however, and this for several reasons. We can't just apply existing works core layout and designs simply translating them to lunar-sourceable building materials. Our design requirements will be rather more demanding. For one, we'll need a fresh air entrance and stale air exit. Lunan homes will be verdant with plants to help keep air fresh, but that should be seen as an a biological "assist" device for the fallback utility air circulation system.

For another, drainage from various sources will likely be segregated to make the water-recycling utility's job no more difficult than it should have to be. Garden runoff, tub/shower drainage, kitchen sink effluent, and toilet wastes all pose different problems for treatment. Not mixing them will simplify the management task and isolate problem areas as they come up. [see MMM #40 NOV '90 pp. 4-5 "Cloacal vs. Tri-treme Plumbing" and "Composting Toilets".]

Those precursor drop in plumbing cores I've seen contain only Kitchen and Bath plumbing connections. We'll want to integrate laundry connections as well. And a new standard feature of Lunan homes will be an inside garden with solar access (whether the residents choose to grow flowers and foliage, or vegetables and herbs, or just patio-side shrubbery is their choice). The Garden will need to be watered and drained.

Finally, we might as well integrate electrical and communications service entrances into the package. That's a lot of stuff to integrate and it is going to take a lot of brainstorming to meet the design challenge with the most space efficient yet follow-on diversity-friendly layout options. To make the challenge even greater, consider that modules will not share walls, just interconnecting entrances. The resulting core package will be a more complex and extensive assembly than we see today in modular and manufactured housing. One suggestion is to pack all these "works" features into a modular entrance node by which all the other "bigger, dumber, cheaper" modular units of the house are reached. Something like a head-trunk "guts" module to which the arms/legs are attached.

The Lunan home must be designed as a functioning organism. It represents and serves as the personal, family-level extension of the settlement's minibiosphere. If you stop and think about it, that's quite a major shift in our philosophical understanding of what a home is. Just as extra-biospheric (trans-Earth) cities that have to host biospheres of their own will be need to be thoroughly reinvented (MMM's "Xities" series, issues # 51-6), so too with settler homes within mini biospheres of which they be capillary-served living tissue.

Perhaps now the reader will begin to see why we did not begin our series on Lunan Homes with a piece on the architectural options and possibilities. The architect too must know what he is up against, within which design constraints he must work. Visual and Solar and Utility access demands are the course prerequisites for Lunar Architecture 101.

MODULAR ELEMENT TESTBED ENSEMBLE

A **For-Profit** Project to Predevelop Architectural Subassembly Elements for On Site Construction.

[**mete** (meet) **n.** *def.:* limiting mark, limit, boundary]
mete: v. to assign by measure, measure, allot; n. boundary

By Peter Kokh

If the Visual and Solar and Utility Access-providing plug-in feature-packed subassemblies we have been talking about are to become standard in Lunan frontier home construction, it might be wise to begin the designing, testing, and debugging of prototype units here on Earth, *while we are treading time* waiting for CATS, cheap access to space, or BATS, budget access, and a more favorable economic climate.

These units can be made of terrestrial materials but for many critical function parts these materials may have to be reasonably close analogs of those we could expect to be available in the curtain-opening era of frontier settlement. In most cases, this requirement should not prove to be an insurmountable challenge. In others, we'll just have to do the best we can with available materials pending development of better analogs (e.g. glass-glass composites or Glax™).

The purpose of the METE PROJECT is to test and compare alternative design approaches and assembly methods. The goals will be simplicity, durability, safety, and minimal failure modes. *This is homework.* No seating in the classroom without it being turned in complete. That the dog of apathy or buck-passing ("that's NASA's job) ate it, won't fly. Surely in the process we'll discover marketable applications galore to Earthside housing. And this for-profit driver should be a big help in getting these design tasks done the "spin-up" way.

Visual Access METEs

Z-View window units withstand the pressure differential between interior habitat atmosphere and external vacuum. Can we use flat glass if we gradually step the pressure with intermediate panes? We can start with laminated safety glass, but ultimately we'll want to test the pressure tolerance of panes of fiberglass-glass composite, the lunar-appropriate solution. Can we make larger windows using convex panes, curving in towards the viewer so as to be compression-stressed by the higher pressure. Glass is strengthened by compression, a fact already put to good use in deep-ocean submersibles. For a stronger assembly, less prone to racking, should we use round frames in a zigzag tubular shaft with elliptical diagonals?

How do we make the seals in a way that not only does the trick but so that the manufacturing and assembly process can be duplicated on the Moon and require the least mass of parts or materials expensively upported through Earth's deep gravity well? What kind of coatings will we need to cut down glare and unwanted heat gain/loss? How simply can we design the mating of our factory-finished subassembly to the habitat module on the job site? How does our METE actually perform in a vacuum chamber?

Less expensive pressure testing might be achieved by placing the METE in a quarter-turned attitude under water so that the parts to be exposed to vacuum are exposed to surface air, and the habitat interior interface is at a depth which duplicates the expected pressure differential. High altitude balloon testing would be considerably more expensive.

Could not at least the footwork on these and other METE projects be channeled through design competitions between engineering and technical colleges? The prize(s) could be put up by an entrepreneur who hopes to make a buck from any terrestrial applications. It's an approach worth trying.

Solar Access METEs

Here we've uncovered a greater variety of distinctive options. Each of these options poses a quite different set of design, assembly, and onsite module integration challenges: Heliostat channeled broken path through a stepped pressurized shaft (akin to the Z-View), clustered fiber optic bundles, and solar hot water skylights or Sun Wells in which plumbing connections and major thermal management are involved.

But in each case we do have something relatively compact to design and test. There is no reason why these design and test, redesign and retest tasks can't be done on Earth. Nor is their any reason to think that these homework processes could not also yield profitable terrestrial applications to suitably reward someone for all the pre-frontier research and development required.

Utility Access METEs

This more complex design challenge would probably be best tackled by a divide and conquer method. College level plumbing, air conditioning, electrical, and communications teams could work separately, periodically coming together under the direction of a systems integration team. Again, at least for the high end manufactured housing market, there should be some marketable applications.

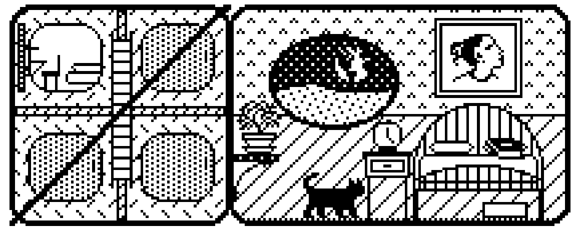
Here too, pressurization elements are of the essence: joints, seals, and interfaces. In this and other aspects, there is ample room and need for the various METE teams to communicate and share insights and findings. Again, there should be marketable developments in this area as well.

Other METE Projects

So much for now. Additional METE project opportunities will be uncovered in future articles in this series, in the area of various interior structure and utility systems needed to turn habitable housing shells into comfortable homes, offices, schools, shops, and factories.

So our goal in this 'Better Lunan Homes & Gardens' series is not just to illustrate and bring to life for the armchair reader some of the ways settlers might "settle in" on the Moon. Our hope is also to inspire and spur on the entrepreneurial "spin-up" ventures that can make some of us (why not you?) some money now. For us the big plus is the frosting benefit of having the satisfaction that we have tone something creative to help enable and accelerate the opening of the frontier. For such work will **help telescope the outpost-into-settlement transition into a much shorter major-money-saving time frame** than if we wait until CATS has put us on site before we begin scratching our heads. Any of you entrepreneurial free spirits out there who'd like to network in brainstorming business plans to get these lunar train cars on track, please do get in touch.

MMM #75 - MAY 1994



***Lebensraum* — Elbow Room in Lunar Settlement Homes**

Personnel on short tours of duty can put up with spartan and ultra-compact quarters - for the duration - witness submariners! They *know* it is *only for a while*. But those who have come with the *intention* of not returning to Earth, perhaps ever, will quickly go stir crazy. They will need much more spacious "homes" in which to "unfold" their presence and feel truly at ease. How will lunar architecture satisfy this need? *See below*

A SUCCESSFUL LUNAR APPROPRIATE MODULAR ARCHITECTURES

pk

One that incorporates these Six Elements:

- **the smallest number of distinct elements**
- **the greatest layout design versatility**
- **the most diverse interior decorating options**
- **fabricated with the least labor and equipment**
- **assembled with the least EVA and equipment**
- **pressurizeable after the least total crew hours**

By Peter Kokh

Relevant READINGS From Back Issues:

[Republished in MMM Classics #1]
MMM # 5 MAY '87 pp. 5-6. "Lunar Architecture"

[Republished in MMM Classics #2]
MMM # 20 NOV '88 pp. 5-6. "Ceramic City"

[Republished in MMM Classics #5]
MMM # 49 OCT '91 p.3.
"Lowering the Threshold to Lunar Occupancy: HOSTELS, Part II, 2) Roomloving functions"

[Republished in MMM Classics #6]
MMM # 53 MAR '92 pp. 5-6. "XITY PLANS, II. Modular Versatility"

Setting the Tone

If we (consortium, settlement authority, government - this applies universally) are not to be overwhelmed by the cost overruns that come from "stretchouts" rooted in financial timidity and shallowness of commitment, the progression from Beachhead to Outpost (demonstrating startup processing and manufacturing technologies) to Settlement must move along swiftly. Once the level of confidence generated by the feasibility demonstrations reaches a critical point, the settlement must be prepared to grow quickly. *Economic self-sufficiency only makes sense if it is achieved without delay.*

We will need a way to provide roomy, safe and secure pressurized shelter, i.e. lunar housing, on a just-in-time basis as the waves of settlers pour in, ready to crew the industries that will supply income-earning exports to Earth. Residential units must be completed, utilities installed, with a minimum of crew hours. In contrast, interior decoration *can* be labor-intensive, pursued slowly over the years. But the habitable shell itself has to be erected 1-2-3.

Assembly-line production of a few modular units that lend themselves to diversified floor plans seem to be the answer. The modules must be designed to connect simply and swiftly - yet securely. This is not Earth: the need to pressurize the whole against the external vacuum is a demanding one.

Speed is just one half of the coin. The other side is the need to hold the labor force involved in module production and on site home assembly to the minimum - so as many settlers as possible can work on production for export. Every part of the design of the manufacturing and construction processes involved must have this *labor-light* goal in mind.

Materials suitable for manufacturing housing modules

Steel and Aluminum or Titanium may come to mind. After all, that is how we build pressure hulls on Earth. But a reality check shows that while iron is abundant, processing out from the lunar regolith soils the various elements that we may want to use to produce iron's alloy, steel, is a bit problematic, especially since no one seems to be doing needed homework on this question. Yet a serviceable lunar steel alloy is much more of a near term prospect than is producing quality alloy aluminum - especially in the context of a small available labor pool, and the need to keep the mass of imported capital equipment to a minimum.

Another theoretical possibility (homework proceeding *without* due haste) is that of habitat module shells and components made of glass glass composites or Glax™. Concrete or Lunacrete is a possibility if economically recoverable lunar polar ice deposits are found. Fired ceramic shells and cast basalt shells have both been suggested, but unless reinforced with fiberglass or steel cables, they might not be up to the job of containing pressurized atmosphere. Our own wager, then, is with lunar steel and/or Glax.

The Size of Lunar Homes – the "Great Home" Concept

We must resolutely and brazenly set aside the notion that lunar settlers shall be forever condemned to endure life in cramped quarters. As long as pre-built shelter must be brought in from Earth, weight limits will work to keep pressurized space at a high premium. Fortunately, by the incorporation of inflatable elbowroom in early expansion phases especially for shared communal functions, "cabin-fever" can be kept at bay.

But once simply and cheaply and easily manufactured housing modules have been designed that incorporate local lunar materials almost exclusively, valid reasons for pioneers to continue accepting constrictive personal quarters evaporate.

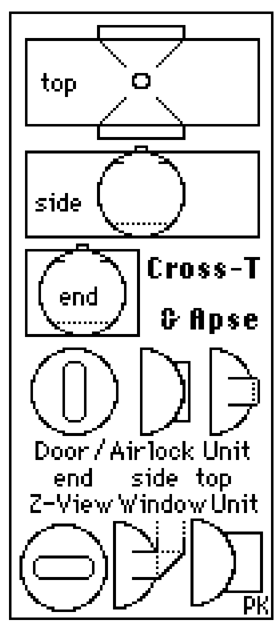
If it can be achieved within the labor and productivity budgets of the settlement, there is no reason why lunar settlers should not request and receive homes that are spacious by American standards. Indeed,

there are good reasons to err in the opposite direction.

First, considering that lunar shelter must be overburdened with 2-4 meters of radiation-absorbing soil, and that vacuum surrounds the home, expansion at a later date will be considerably more expensive and difficult than routine expansion of terrestrial homes. Better to start with "all the house a family might ever need", and grow into it slowly, than to start with initial needs and then add on repeatedly. Extra rooms can, of course, be blocked off so as not to be a dark empty presence. But they can also be rented out to individuals and others not yet ready for their own home, or waiting for one to be built.

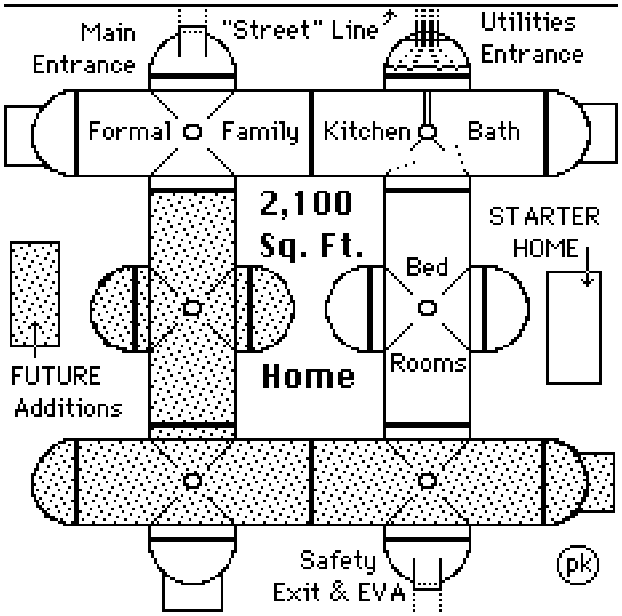
Even more sensible is the suggestion that the extra space will come in handy for cottage industry in its early stages, before the new enterprise is established, matured, and doing enough business to be moved into quarters of its own. At the outset, with every available hand employed in export production, the demand for consumer goods, furnishings, occasional wear, arts and crafts, etc. will *have to* be met in after-hours spare time at-home "cottage industry". The lunar "Great Home" could meet this need elegantly.

"A Minimum # of Modules"



At left are shown 2 basic modules: a 4x12 m (= 13x40 ft) cylinder with open ends and expansion openings to each side. These units can be chain- or cross-linked, but ultimately, all remaining openings must be closed by an apse or hemispheric cap. Four versions are suggested: simple blind cap; cap with door (to the "street" or to an EVA airlock); cap with periscopic "picture window" unit, and cap with utility service entrances: fresh/drain water, fresh/waste air, electricity, telecommunications, etc.)

Our suggestion is that the water-using functions be concentrated in a cross-T module with a side utility entrance cap. Two phases are shown. But we recommend the whole complex be built together.

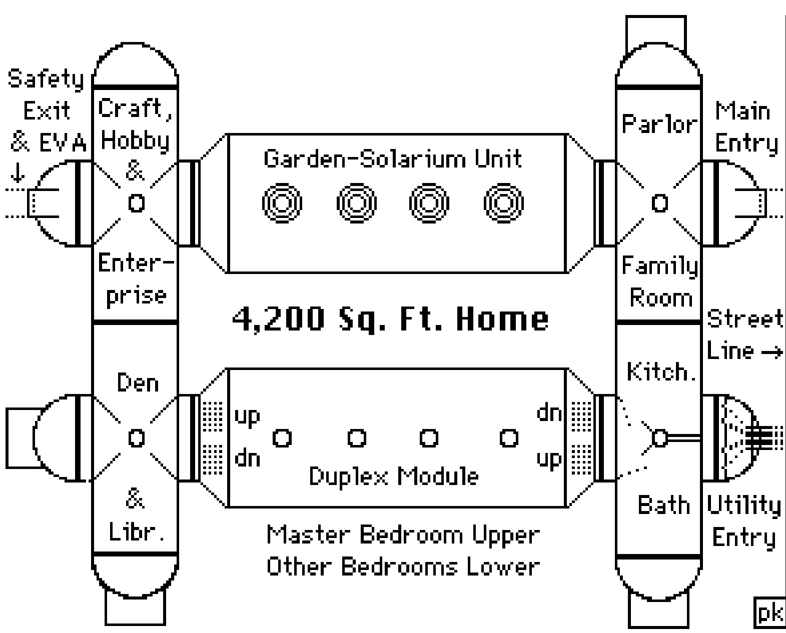


Add a third larger module and presto!

As soon as the settlement's module manufacturing facilities are able to produce longer, larger diameter units capable of being configured into two floors, more spacious homes can be built with less modules on less land. At right is a "Great Home" plan that incorporates two of the larger 6x20 m (20x66 ft) modules. One has a master bedroom above and two or three smaller bedrooms below.

The other has no middle floor but is equipped with larger sun ports and houses a Garden-Solarium that quite literally brings the home to life, producing herbs, spices, and fruit and vegetable specialties for home use and possible sale. The unit includes a patio for nature-revivifying rest and relaxation.

This spacious Great Home or Mare Manor includes ample space to pursue hobbies, even to start up a cottage industry. It is assembled all at one time.

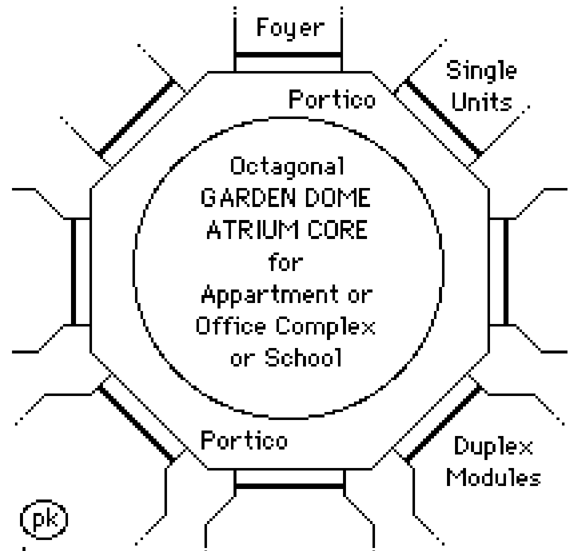


The settlement will need more than homes

As it grows, there will also be a need for larger constructs to serve as apartment blocks, office complexes, schools, clusters of shops, and so on. One way to combine the three modules previously described in larger clusters is to provide a larger polygonal atrium module. We chose a 12 m (40 ft.) diameter octagon for our illustration, simply because our MacPaint drawing program doesn't do hexagonals well. Here we have an atrium floral and foliage garden with a peripheral portico balcony leading to the entrances of other single and double-floored cylindrical modules.

Other specialty connectors could introduce even more diversity in module layout options. Hex nodes, equilateral Y nodes, Y nodes with the fork separated by 90˚ instead of 120˚, longer, and wider cylinders, torus segments etc. The result would be an ever more expressive homegrown architectural "language". Yet the 4 basic modules shown here should be able to put together a respectable town.

Not to be forgotten are the larger diameter cylinders with side ports of which the settlement's residential and business streets are made.



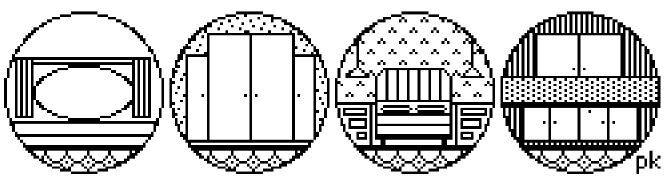
The search for the best modular architectural strategy, one that meets all the challenges listed at the outset of this article, will certainly benefit from being tackled by many minds. The sketches above are suggestions. Perhaps there are far better solutions than those which have occurred to me.

The Apse or End Cap – Challenge or Opportunity

In comparison with terrestrial homes of whatever style, the distinctive feature of homes on the Moon (or Mars) (that are not within an atmosphere containing megastructure) is their curves. The structural stresses imposed by pressurization and the need to minimize failure constrain basic shell choices to sphere, cylinder, and torus, and combinations of the above. Floors will be flat, of course, as will be added interior walls. But decorating and furnishing outer side walls that are curved will present challenges. The ways these challenges are met will contribute much to the distinctiveness of Lunar (and Martian) Homes. If you look again at the design offerings on the preceding page, you will notice that on average, the cross-T cylinder module, with 4 vectors for expansion, has other cylinders at 2 points, and apse end caps at the other two. These hemispheric alcoves seem to be everywhere.

Will the Lunan homemaker look at these odd-shaped spaces as nuisances, places to stuff odds and ends or stick something distractive? I rather suspect that instead a number of enterprises will arise that find a suite of ways in which to turn this layout liability into a real asset. While these end caps will probably be erected as empty shells - some of them with factory installed entrances or "Z-view" windows, others with factory installed utility service entry connections, others plain and "empty". And as usual, those who come up with ways to productively fill such alcoves will find a ready market for their "product" among those less creative or imaginative. There is a market here, not for factory installed "built-ins", but for post home-raising tailored "snug-ins" with a built-in look. This thoroughly standardized space is the perfect opportunity.

Some obvious solutions are: √ closets and storage units; √ audiovisual entertainment centers; √ "Murphy- bed"-reminiscent fold down beds with night stands, lighting, etc. for a supplementary bedroom; √ a non-hide-away version of the same thing; √ dinning room buffets; √ kitchen cabinetry and pantries; √ breakfast nooks; √ library-den shelves and cabinets; √ devotional center or chapel; √ bathroom equipment; √ an exercise center; you get the idea.

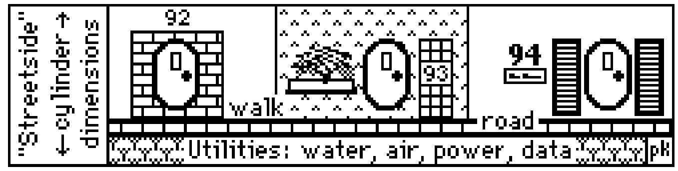


We have not yet talked about interior wall decor (next issue) or distinctive lunar-appropriate furniture and furnishings (later issues). But the architectural implications for lunar home interiors are already becoming obvious and interesting.

On the street where you live

Like terrestrial homes, lunar versions will have a certain front door/back door polarity. Here, however, the back door may be included less for convenience (handy to the kitchen and/or garage and/or kids' outdoor play area, as for safety - an alternate way out in case of emergency. Whether the back door leads to a pressurized "alley" or serviceway (that would be a convenient feature) or simply via an EVA airlock to the surface vacuum, is another question, one to be given careful consideration by the city planners long before the first home is erected. If there are such a pressurized serviceways, utility entry connections (air, water, power, data) can be located alleyside rather than 40 ft. from the "front door" on a single street as shown in the illustrations above.

While homeowners in general need not be concerned with the "external appearance" of their buried home [but see "Moon Roofs" in MMM # 55 MAY '92 p. 7] they will have the opportunity to do something distinctive with the areas of the street cylinder wall adjacent to the doorway to their homes. They can choose the anonymous unimproved look, or do something distinctive to the door itself, most likely in the way of approved appliqués, or the trim or "matting" around the door framing. For this purpose brick and tile and lunar rock (as is or cut and/or polished) are some of the obvious possibilities. And certainly some doorside landscaping as space permits, at least wall-hung potted plants. Entrepreneurial concerns will arise to meet the universal psychological need to signal personal uniqueness at the public entrance to one's personal world. ***PK***



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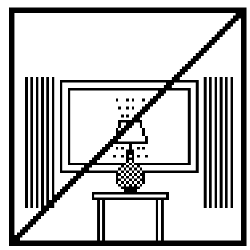
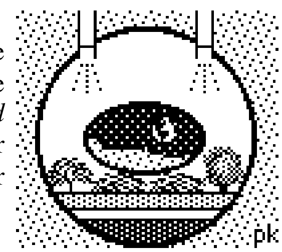
Windows - out with one cliché, and in with another



Driving along at night one sees home after home with a lamp on a table in front of the picture window? Poor decorating actually, but commonplace. On the Moon, with very little pedestrian or motor traffic "outside", exterior "presentation" will rate low.

Ranking higher will be the need to gaze on the stark moonscape *through the reassuring foreground of living foliage and flowers*, under solar spotlights. More on lunar homestead interiors, *below*.



[Editor: the author of the series of pieces that follows has his own one man "This Old House" business and specializes in custom home interior remodeling and redecoration. His hands-on experience working with all sorts of building and construction materials and in getting the most out of them under oftentimes difficult conditions has filled him with enthusiasm for this "ultimate challenge" to homecrafting resourcefulness.]

INSIDE Moon Manor

by Peter Kokh

In the previous issue we speculated a bit about the possibilities for a modular lunar-appropriate homestead architecture reliant on locally produced building materials. Until such a far off day arrives when new homes are built within atmosphere-retaining megastructure units, traditional box-type homes are ruled out. The need to contain atmosphere against a vacuum under a protective shielding overburden will result in homes with curvaceous exterior shells or "hulls": curved side walls and ceilings and cylinder end caps. Such shapes can be put together to yield a great variety of floor plans and layouts.

We learned that the alcove-like spaces of hemispheric cylinder end caps will be an opportunity for “snug-in” furniture with a built-in look. We saw too that these caps are the logical modular element by which both visual and personal access is provided, in alternative versions.

In this issue, we take a further peep inside the Lunan homestead. We’ll look at the building materials likely to be available in the early settlement and their implications for interior decorating options. While Lunans will have less choices, with resourcefulness, a great deal of decorative variety should be possible, nonetheless.

Manufacturing and Assembly of INTERIOR WALLS

by Peter Kokh

So far, our speculative Lunan Homestead is just a shell, one continuous labyrinthian space. In a pinch, that’ll do. Heck, we can string up a blanket or sheet to provide privacy where needed, but that is certainly no long term answer to the need for structured, subdivided space to house a variety of rather different activities. We will want interior partitions or walls and interior doors and doorways. These can, and will be added afterwards - after construction and pressurization and utility hookup, and after the new occupants take possession. For as we have seen, the need to provide safe basic shelter in as timely a fashion as possible will be paramount. All other “secondary” shelter needs will have a much lower priority, that is, no real urgency at all.

All the same, how will we provide partitioning? We won’t be able to order a load of 2x4s and dry wall sheets. Even if the settlement farm can produce wood as a byproduct, the young biosphere can ill afford to see its carbon and hydrogen content withdrawn from quick turnaround circulation to be “banked” instead in so comparatively frivolous a pursuit.

If indeed economically recoverable lunar polar water-ice deposits are found, then gypsum, the hydrated calcium sulfate used in dry wall could be produced. To produce dry wall or sheet rock itself, we’d also need a substitute for the paper/cardboard surfaces used to sandwich the gypsum in sheets. Some sort of tight-weave fiberglass might do. This lunar dry wall could then be used with steel 2x4s now widely used in fireproof construction.

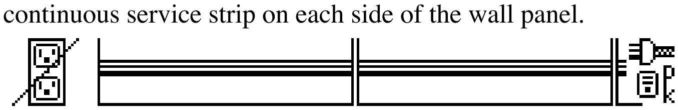
Baring this fortunate orbital prospecting find, and subsequent ground truth confirmation, the more likely building materials for walls are steel and aluminum panels, with steel easier to produce for the early settlement, and glass-glass composite (Glax™) panels, the same likely stuffs used in fabricating the homestead’s modular shells themselves, making for consistency in decor treatment . Brick, sinter block, and glass block are likely to have limited application where the permanent decorative look and feel they provide meet the original homesteaders’ needs and desires.

Will available building materials be brought into the homestead from the warehouse with fabrication to take place on location with all the attendant dust, debris, and cut off waste? This may be the custom on Earth where the specifications of the particular job vary enormously. But for Lunan homesteads built of lunar-appropriate modular construction elements, the wall-spec variations will form a very limited set. Walls will either fit spherical cross-sections of cylinder modules or center or near-center rectangular sections along the length of the cylinder. In either case, they can be manufactured with in-factory efficiency for onsite snap-fit erection by again designing a very limited number of modular elements.

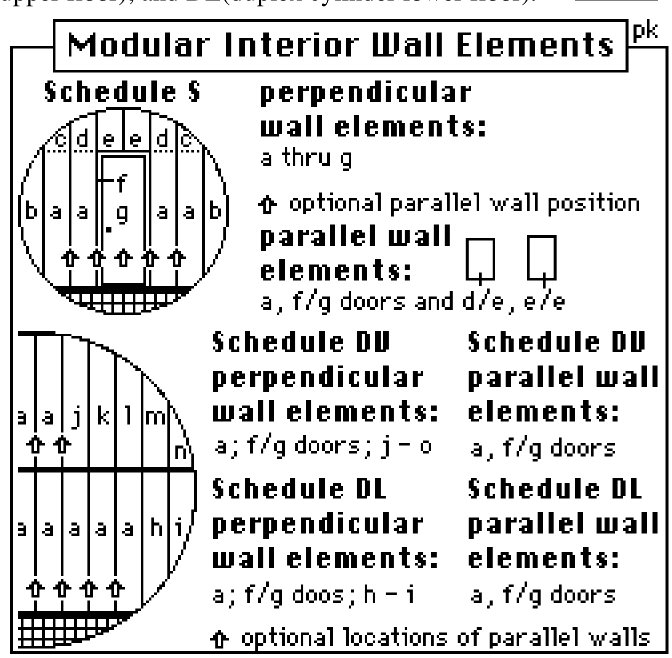
We suggest wall sections of a varying ceiling contour and height but with a standard 50 cm (19.77”) width. A double clear space would provide a “rough opening” for a door 1 meter wide (i.e. 30.54”, and why not 2 meters i.e. 79.08” high). If each module has a pair of retractable pegs or dowels on both bottom and top to fit matching holes pre-drilled into floor and ceiling on a 50 cm (half meter) grid, the modules could be put together to make a wall easily, and taken apart and reassembled elsewhere when desired.

The modular wall elements could be hollow or honey-combed, with or without inner acoustic insulation. Each of the various elements could be equipped with surface screw actuated KD [“knockdown”] connectors for easy mating. Surface screws would also actuate panel to floor and panel to ceiling pegs or dowels.

The various wall panel elements might also each be fitted with male-female electrical interconnects feeding one continuous service strip on each side of the wall panel.



If our suggestion for modular architecture were to be adopted, 3 principal “schedules” of wall module elements would do the trick: S(single floor module); DU(duplex cylinder upper floor); and DL(duplex cylinder lower floor).



SURFACES & Trimwork

An Exercise in Resourcefulness — and Creativity

by Peter Kokh

Unavailable on the volatiles-impoverished Moon are:

No
Woodwork trim moldings
Wood and wood byproduct **paneling**
Plastics and hydrocarbon-based Synthetics
Wallpapers and wall coverings of all sorts
Oil (Alkyd) based **paints**, stains, varnishes
Latex (Acrylic) based **paints**, stains, varnishes

Still available for the resourceful homesteader are:

Yes
Steel, and **Aluminum**
Brick and **cinder block**
Ceramic tile - however, no lead-based deep colors and no lead-based high gloss glazes
Glass & Fiberglass-glass composites - Glax™
Pyrite (FeS_2) brass-colored surface coating of steel
Waterglass/oxide based* paints, stains, varnishes and "texture paints" with regolith pastes Titanium or lime (calcium) "whitewashes"

[* NOTE: No known experiments to date but LRS-sponsored R&D to begin shortly, and to include application tools.]

And IF water ice is found in quantity at the poles:

Maybe
Concrete ("lunacrete", fiberglass reinforced)
Plaster or **drywall** (hydrated calcium Sulfate)

The "ultimate resource" of any Settlement is the talent pool & creative resourcefulness of its people — not mere natural endowments.

Background Readings in MMM's Past

[Republished in MMM Classics #7]
MMM # 63 March '93 pp. 4-11: Beneficiation; Sintered Iron; Alloys; Glax; Glass; Ceramics; Color the Moon.
MMM # 65 May '93 pp. 5-6. Sulfur; Moonwood

[NOTE: **A word about Prerequisites:** the discussion that follows assumes that the necessary homework has been done in learning how to isolate, under realistic lunar conditions, all the "workhorse elements" needed to make a useful stable of alloys, glass formulations, and colorants. See MMM # 63 reference above. Very little of this homework backlog has been done by NASA, by industry, or by capable individuals. It is MMM's belief that much of the know-how needed on the lunar/ asteroidal/space settlement frontier can be pioneered *for profit here and now, solely for the terrestrial applications*. All that is lacking are motivated and talented entrepreneurs.]

Design Preferences: Simple Minimalism vs. Ornate Maximalism

There *has to be* a balance in life. In Victorian times a century ago, when life and living were far simpler (or do we simply forget the problems of times gone by) home interiors were customarily ornate, excessively so by today's standards. The wood furniture was highly carved, of complicated design, and often with marquetry inlay and other embellishment. Wallpapers and fabrics were "busy". Things made of iron were full of curves and flourishes.

The `Art Nouveau` period that followed freed the curves from symmetry, replacing that sacred cow with free spirited "balance", yet keeping all the curves in homage to nature. `Art Deco` came along and substituted the rectangle, triangle, and diamond - straight lines and hard angles in general, but keeping the new free spirit.

Then we languished in a state of eclectic poor taste for lack of inspiration. From this we were rescued by the simple straightforward "form is function" and "simplicity is elegance" of modern design. Many enduring different fountains of creativity here: Frank Lloyd Wright, the Bauhaus, Danish-Scandinavian design - to take a broad potshot at the spectrum.

Modernism installed a slavery of its own. Happily these days, we are each free to express ourselves as fits our own soul's needs: with simple, graceful, minimalist elegance - or with wild, life-embracing detail - or anywhere in between.

When it comes to our picture of the future - and of space - the image of steel and plastic and plain lines has taken on a life of its own with no basis or justification at all in reality. In many frontier situations, plastics and synthetics will be prohibitively expensive exotic import materials. More to the point, the barren desolation of most, if not all, settlement settings in contrast to the lush host biosphere we all enjoy on Earth (even in the desert, even in the tundra) will stuff the pioneers with as much simplicity as they can bear, perhaps more. The deep psychological need will be for homes that are oases of rich detail and interest in this design desert.

Many of the suggestions for decoration illustrated below will strike the reader as being out of touch with today's spirit. We protest that today's spirit bears no relevance to the needs of the frontier. Frontier lives will be difficult, but hardly as over-structured and complicated as is common in our own contemporary situations. The one thing that will hold true for them as for us is that overriding cosmic need for *balance*.

Variety in a small market

What is needed is not only a number of different ways to decorate with interest, *using few basic materials*, but also ways in which to *customize* the effect. For manufactured items, computer assisted manufacturing or CAM offers promise. It has traditionally taken hours to effect setup changes in machinery to alter the product design or finish, and only premium cost or large demand justified the loss of productivity such change-overs required. Nowadays, smart machines can customize each item without missing a stroke. A small market and small total product run need not mean that only one kind of anything is made, that everyone's wares and wears are indistinguishable.

At the same time, such "kaleidoscope machines" have limits. And the role of art- and craft-finished items will be important. Scarcely in history have artists and craftsmen enjoyed as much prestige as they will on the frontier. Never has the personal touch been as valued as it will be. To serve this need, some quantity of every item might be made "ready-to finish". The trick is to design items that *can be* finished in an open variety of ways, either by the professional, or by the do-it-yourselfer working to his/her own satisfaction.

This will apply especially to furniture and furnishings. But we jump the gun and bring up the subject here because it applies to surface finishing in general. And living spaces as defined by floor, walls, and ceiling are an important instance.

The surfaces in question will include metal (steel, later also aluminum), glass, glass composite, ceramic, and cast basalt, and sintered regolith block — plus lunacrete or plaster or lunar dry wall *only if* water ice is found to be abundant.

Surface treatments: metal can be embossed, engraved, and oxidized (rusted) or pyrited (sulfur treated for the brassy yellow look of fool's gold); it can be polished or sanded for a shine or satin sheen. It can be chrome-plated, or stainless.

Glass and glass composite can be stained and etched and mirrored. Cast basalt can perhaps be given the mold-transfered look of crosscut sawed wood, of bark, leaves, or other "nature collages". Sintered regolith brick can perhaps be produced in pleasingly variegated grays with homogeneously colored regolith in waterglass serving as mortar. Tile can take on the color of oxides, left unglazed or given a salt (sodium) glaze. Vitreous glazes without a lead-based flux are possible in many colors and hues, even if neither bright nor deep.

Surfaces with sufficient "tooth" or fine-scale roughness can perhaps be whitewashed with titanium oxide or calcium oxide (lime) powder suspended in a waterglass medium. Perhaps colored oxide pigment powders in the same medium can be used as paints. We see that there is plenty of room for experiment and the promise of amazing variety.

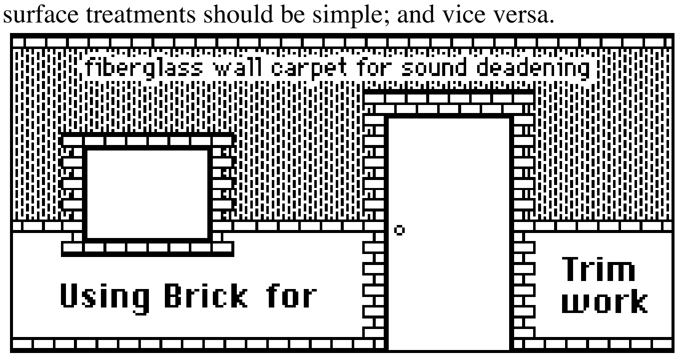
Special wall and trim treatments

Woodwork, to which we are so accustomed in our homes the world over, is not a lunar-appropriate choice. While good "furniture quality" woods could be produced by apple and cherry orchard trees, the settlers will not be able to afford to withdraw and bank that much incorporated hydrogen and carbon from the biosphere-food production cycle.

One option is the "trimless look", a natural for manufactured walls and wall module systems. For example, door and window frames are seamless features of the adjoining wall (modules) and not set off in color, texture, or any other visible way as "border" areas. I've seen such a look in Mexico City's D'el Angel Hotel, and it is strikingly refreshing.

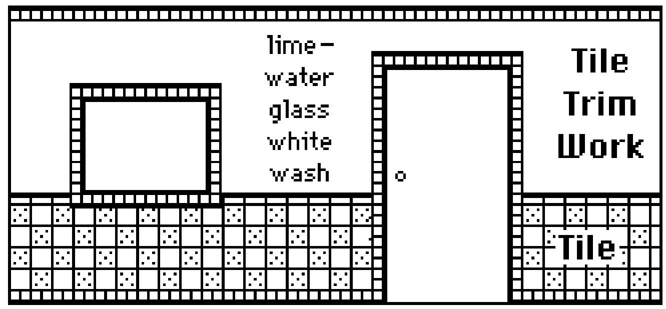
But where desired by the homesteader, the edging and border setoff function of *wood*work, can be simulated by lunar-producible inorganic materials such as thin veneer (Z-)brick, ceramic tile, and metal "**trimwork**".

These choices are illustrated below along with several possible companion wall surface treatments. As a general rule of good taste, when the chosen trim is ornate in feel, wall surface treatments should be simple; and vice versa.

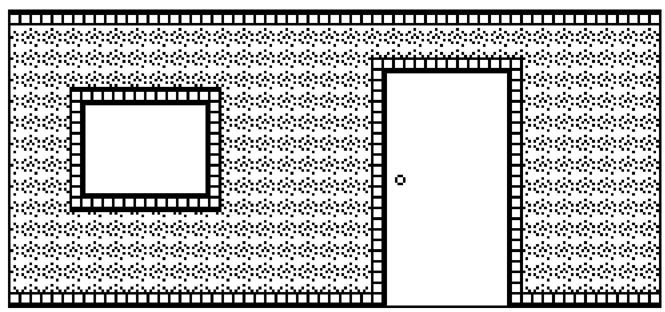


In the illustration above, the soft look of "carpet" is chosen to balance the rough look of the brick veneer. However, as organics and synthetics are not available for this purpose, and fiberglass carpet would wear poorly, being too brittle to take repeated crushing of the fibers, the latter is applied to the upper walls, out of harm's way, so to speak, but still contributing to the sound control and providing visual softening.

In the illustration below, ceramic tiles are used to provide trim borders. While the seemingly endless variety in color, pattern, and glazing now available on Earth could not easily be produced on the Moon, a variety of hues from the lunar palette (regolith grays, oxide colors, stained glass colors) should be available either unglazed or in soft satin glazes. Tile in contrasting sizes, and coordinated colors and patterns, would make a good companion wall finish, as would simple white-wash or waterglass-based paint.



Simulating the "wallpaper look" with lunar paints

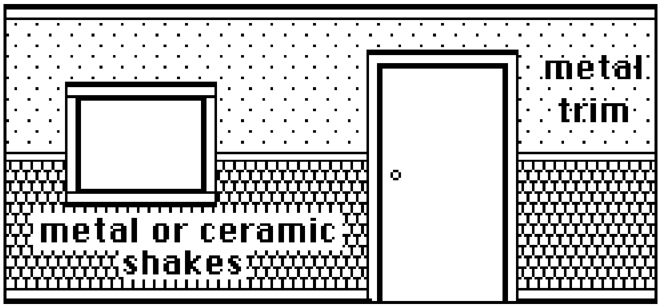


In this schema, the walls are first primed with a "whitewash" of lime in a waterglass solution. When this is dry, any of a wide variety of wallpaper like patterns can be sponge-painted over the base white, using metal oxides, again in a waterglass medium. Imported natural sponges of various textures and shapes can be used over and over again as the "paint" is water soluble. The technique is much faster than wallpapering and the results can be "painted over" when a change in color and/or pattern is desired.

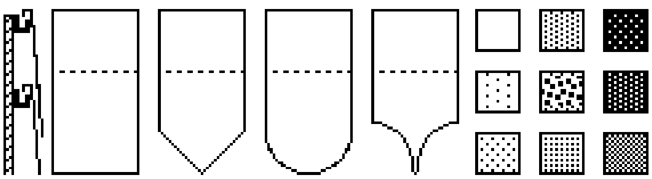
Projecting a transparency of a scene or panorama to be transformed into a mural, one could follow the pattern with variously textured sponges dipped in various waterglass-metal oxide "paints" to create a result with an "impressionist" feel.

Other possibilities with waterglass-based coatings are in need of investigating. How about applying a clearcoat of waterglass and while it is still wet, random- or pattern-flocking with dry oxide powders or regolith powder? This could be done on site with by blowing through a hopper-fed (self-choking feed) straw equipped with variously shaped nozzles to alter the dispersion pattern (as in decorative cake-icing devices). Under factory conditions, flocked panels could be produced to order by computer controlled blower-printer. What would the effect be like? Has anyone yet tried anything of the sort? I suspect not.

Metal "shakes" as a wall treatment choice

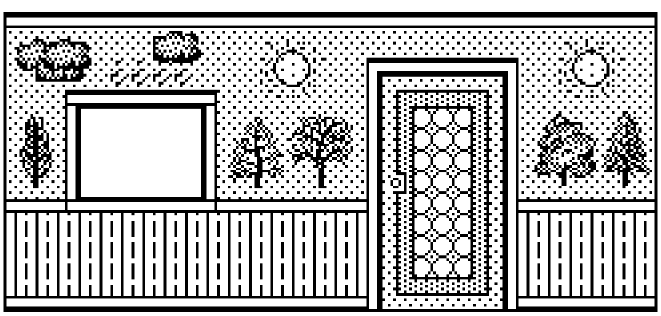


Using a repertoire of four differently edged shingles, each available in any of a repertoire of waterglass-oxide colors, a large-pixel mosaic tableau can be created. Working up from the floor, the metal shingles could snap into horizontal channels prepositioned on the wall, with a special topper strip. A computer could analyze a picture, pixelize the pattern and color codes, and list the elements to be purchased.

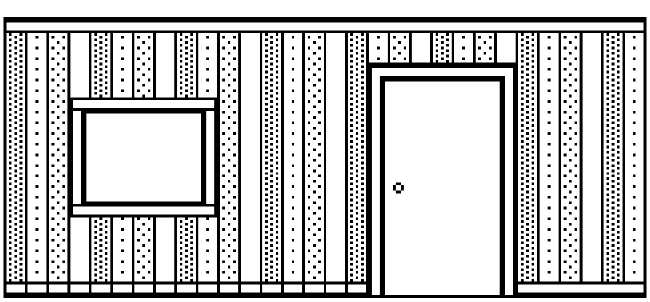


Geometric and Pictorial Panels of Embossed or Beaten Aluminum "Sculpsheet".

If Lunan metallurgists can formulate an alloy of steel or aluminum malleable enough to permit the kind of sheet working that has long been practiced in copper, brass, and tin, *bas relief* patterns or tableaus could be either mass produced in a number of popular styles, or handcrafted on commission. The patterns or scenes might be "highlighted" by careful use of waterglass-oxide "varnish-stains". This form of wall treatment might be an attractive choice for dens, libraries, formal dining rooms, entry ways, even for "front door" facings.



Less ornate and ambitious would be steel "paneling" of interlocking or tongue in groove narrow strips. These could all be finished alike or vary in a set sequence. Finishes that might be used include stainless with smooth, embossed, or satin-finish, chrome, and Pyrite surfaced steel. The latter, being of false gold, iron sulfide FeS_2, would have a brassy-yellow finish. (Brass and copper are not lunar-available).

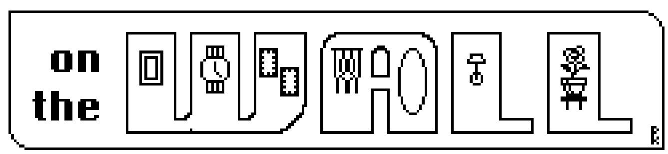


Artist–Craftsman, Tradesman, & Do–It–Yourselfer

The settlement market should work to ensure the entrepreneurial supply of a number of satisfactory alternatives for three overlapping degrees of expertise, talent, and available effort. Within each there should be choices to fit various budgets. The result will be a surprising and spicy variety between individual personalized lunar homesteads.

Special Wall Surfaces

Tub surrounds, shower walls and sink back-splashes can be *glax* one piece units, of standard size and shape and fitting interfaces, available in a variety of colors and patterns and textures, thanks to the ease of setup changes possible with computer-aided manufacturing methods. MMM



Problems & Solutions for Hanging Stuff

by Peter Kokh

On Earth, it is no problem to hang something on the wall: pictures and paintings, macramé hangings, copper and wire sculpture, plastic bric-a-brac, mirrors, wall lamps and candle sconces, knickknack shelves, shelving systems, clocks, or whatever else is not too heavy and not too deep as opposed to high or wide. The reason it is not a problem is that the sundry wall stuffs we build with such as plaster, dry wall, and/or wood are all medium density materials. They are soft enough to pierce with a nail or screw, and firm enough to hold such fasteners. Even concrete, brick, and cinder block - all denser and harder - have fastener systems designed for them that are more difficult, but not impossible to use.

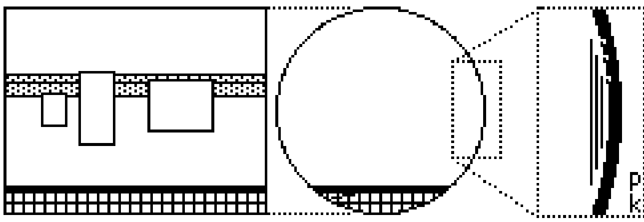
On the Moon, the most probable wall materials are steel, aluminum, and glass-glass composite or Glax™. These are very dense materials, and while it is possible to drill holes into them, "repairing" the "damage" when one wants to redo a room and hang the same or other items elsewhere, exposing old wall-wounds in the process, is something else.

Cable-wrapped fiberglass reinforced lunar concrete is a remote possibility as a hull material. Some sort of cinder block is a conceivable but unlikely material for interior walls. For either of these, however, a waterglass-regolith mortar should be available in a wide range of gray shades. But as these wall materials are the less likely, let's concentrate on the problems posed by metal and glax.

If repairing “nail holes” is the problem, the simple answer is not to make any in the first place. Yet our Lunan homesteaders will want to personalize their quarters not only by room surface decoration (paint, paper, panel, trim) but by hanging artcraft items and other objects “on” the wall. So we are faced with a design problem: how to design walls so that hanging things on them requires no added hardware, no added holes, etc.? We *could* limit ourselves to steel walls requiring only magnets. But let’s brainstorm a bit more thoroughly.

Our settlers will face two situations: (a) curved outer hull walls (either cylindrical or hemispheric concave surfaces); and (b) flat interior walls. Most likely the kind or at least the size and placement of things we will put on curved surfaces will show more restraint than the total freedom we are accustomed to enjoying with traditional flat walls.

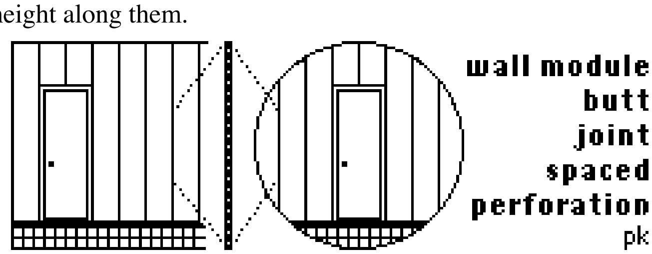
On the horizontally concave outer walls of cylinder modules, only the central portion is suitable for holding things flat so that both top and bottom of the object ‘touch’ the wall.



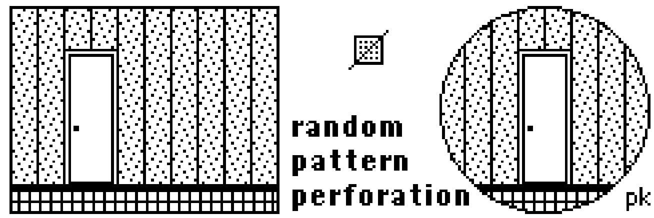
For this purpose, a series of built in hanging strip grooves is a solution that may work, and even presents decorative possibilities, i.e. as a broad horizontal stripe. Objects can be then hung anywhere along the length of the wall, utilizing the hanging groove that best suits their individual height. While the result may be that pictures and other objects are hung slightly below the customary “eye-level”, the hanging grove stripe, perhaps differentiated by texture and/or color from the rest of the wall, will be at the top of this range, serving as a visual corrective of sorts.

This hanging system can be repeated on flat interior walls, especially if one wants to continue the visual effect of the color/texture differentiated hanging stripe. If not, i.e. if one wants more freedom for flat interior walls, then the hanging “stripe” should be visually minimized by not distinguishing the space between the hanging grooves by texture and/or color.

Bearing in mind the suggestion that interior walls be modular, with sections 50 cm or 20” wide, then the butted edges can be “perforated” to allow hanging objects at any height along them.



The constraint of having to space sundry hangings on 20 inch centers may be acceptable to some, not to others. An elegant alternative might be *random* perforation of the wall panels themselves. The result would not look like “pegboard” for two simple reasons: first, the hole spacing would not be in noticeably vertical and horizontal “rows”; second, the holes would be much smaller, say just large enough to admit a 6d (6 penny) nail, slanted downwards to a depth of say 1 cm or 1/2 inch. The effect, both visually and *acoustically* would not be unlike that of some acoustic ceiling tiles.



There is, of course, ample precedent for “nail hole control”. Many rental and lease agreements stipulate that the tenant or lessee must either repair any holes made, or use adhesive hanging methods - neither a practical option for our settler, given the wall materials likely to be in use. However, much earlier in the present century, it was common to place a “picture hanging molding” just below the ceiling. Anything hung “on” the walls could then be suspended by decorative cords, clips, and tassels from such a molding. That is a look long out of favor and not likely to find fresh converts. But it embodies the philosophy of built in “purchase points” for hanging various items “on” walls that we’ve tried to borrow.

Again, what we have tried to do is to illustrate the *distinctive look* of Lunan homesteads that is likely to flow from the constraints inherent in the building materials settlers are likely to have as options. With resourcefulness, such restrictions will trickle through to homes no less custom personalized, nor less beautiful than those left behind on Earth. While options will be less, the possibilities are varied enough that no one will be able to say, “when you’ve seen one Lunan homestead, you will have seen them all.” And in a world many magnitudes of order “smaller” in population, the pursuit of distinctive variety for its own sake will be intensely pursued.

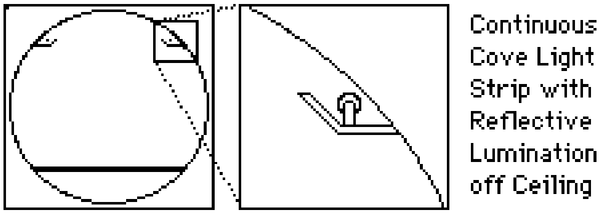
A large part of our sense of world, is not just *size*, but wealth of *diversity* and variety - in scenery and terrain, in . plant and animal life, in climate, and in architectural and interior decoration styles. With first just one, then a few more settlements and outposts on the Moon, the settlers will turn to variety in home decoration, not only as the spice of life, but as the principal way of validating their new adoptive satellite as a human *world* - one with *depth*. MMM

ceilings

pk

by Peter Kokh

How do you define “ceiling” in a habitat space in which the walls curve up overhead and over into one another without any break in the flow? If there is a cove well above eye-level to support ambient cove lighting, the area between the coves might be pragmatically defined as ceiling.



In some decorating schemes, dark ceilings have been used especially to visually "lower" them when the actual height is too high for one's taste. Ceilings have also borne lavish decoration. The Sistine Chapel in the Vatican is the most famous example (the one in the Governor's Conference Room in the State Capitol in Madison comes close enough). But recall also the molded tinplate panels that were commonplace in commercial halls at the turn of the Century (19th to 20th).

But overwhelmingly, ceilings have served as indoor surrogates for the sky, surfaces meant to reflect ambient light brightly. Accordingly they are traditionally painted in flat or other soft white are light pastel shades. On the Moon, we'll probably see examples of both. The ornate design showpiece may be a high end budget choice as a focus of attention for meeting places, banquet halls, and just plain dining rooms.

But overwhelmingly here on the Moon where the outvac sky is black, the Earth-reminiscent overhead brightness of the sky will be repeated in homestead ceilings as repositories of soft rich unfocused reflected light. For this purpose a waterglass Ti_2O (titania) and/or CaO (lime) whitewash should work. If a blue oxide pigment can be produce, we predict sky blue will quickly replace white as hue of choice.

flooring

pk

by Peter Kokh

In the context of the modular Lunan homestead, three subtopics of interest suggest themselves when it comes to floors and flooring. These are *structure* - how they are built and installed, *function* - what purpose these structures might serve besides providing surfaces to walk on and set furniture upon, and *finish* - what they might look like and feel like underfoot.

Structure: In sixthweight (1/6th G) truss members can be much less massive. We are talking about short 10-20 ft. (3-6 m) spans. Floors and truss/joists can be integral panelized elements, and in the case of two-story applications, incorporate ceiling surfaces as well. Since customer customizing does not seem to be in question, they might best be designed for more efficient factory-installation module by module prior to assembly of the separate homestead modules on site.

Function: if flooring is panelized or modular, ought it be removable? Removable decking could give access to storage space underneath as well as to utility runs (plumbing, ventilation, electrical, communications) connecting the various modules. Yet to the extent trouble free systems are involved, ready access looms as a less important requirement. Nor is subfloor storage especially convenient. More, it might interfere with some finishing options, e.g. installation of ceramic tile.

Fixed flooring could 1) serve most of the utility run needs 2) incorporate a radiant in-floor heating system, the most efficient and comfortable form of heating yet devised, 3) top off a thermal mass reservoir. The latter would be especially attractive if some lunar-sourceable form of eutectic salt can be discovered. [A eutectic *salt* is one that changes phase from liquid to solid and back at a convenient temperature in the mid ambient range with a relatively large heat input/output i.e. storage/release.] To my knowledge of lunar resources, that is an unlikely prospect, however welcome it would be.

Finish: On Earth, popular flooring choices include carpeting, wood plank or parquet, vinyl tile or sheet (linoleum), slate, and ceramic tile. On the Moon, only the latter is a real possibility, along with steel, glass composite or Glax™, and tiles, bricks, or slabs of cast basalt.

Carpet can be made of natural or synthetic organic fibers. In either case, for lunar application, it would tie up priceless hydrogen, carbon, and possibly nitrogen that is best used to maintain and grow the biosphere. What about carpets made of fiberglass fibers? After all, fiberglass draperies are a common choice. The problem is that for all their strength, glass fibers are brittle and stand up poorly to wear, and other abrasive abuse. For draperies that is not a problem. Underfoot it would never work. However, glass fiber carpets could still be applied to walls, out of harms way, there to contribute to acoustic control and visual softening.

Cast basalt pavers are the one possibility mentioned that deserves the most homework. Baring that, ceramic tile and textured steel, pyrited for color, will be the workhorses.

If carpeting is out, perhaps throw rugs made of discarded clothing are not - especially clothing made on Earth, gaining passage as the allowable maximum of settler recruit clothing, and produced through "unkosher" processes that make recycling and/or biodigesting of the constituent fibers difficult or "not worth the effort". But is it not more likely that most recruits will head the request (if it is not indeed a requirement) to bring along only recyclable clothing? At any rate, in sixthweight, expensive resilient material is more efficiently invested shoe soles always in use, than in carpet that for the most part just lies there.

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

T. S. Eliot in "Four Quartets"

MMM #77 - JUL 1994

[Editor: one of the stints on the author's resumé is that of former furniture salesman in the early 70s. His familiarity with furniture and home furnishings earlier and continued to broaden thereafter.]

INSIDE Moon Manor

Part II: Furniture and Furnishings

by Peter Kokh

In the previous issue, we took a look at "the look" of Lunan homestead interiors, insofar as they will be constrained by the materials to which settlers may well be limited.

In this issue, we take a further peep inside the Lunan homestead. We'll look at the list of furniture-making materials likely to be available and how Lunan furniture designers might express themselves in such media. Then we'll take a non-exhaustive look at furnishings or accessories. These articles will complete this MMM series on first generation Settlement Quarters. Related pieces will appear occasionally.

Cinderella

It might seem that without wood and plastics, stuffs for furniture making available on the Lunar Frontier only at exorbitant cost, compensated by a corresponding reliance on such New Stone Age materials as metal alloys, ceramics, glass, and glass composites, that the "Style", if any, achievable by Lunan furniture designers, will not much surpass those of the Golden Age of Bedrock way back in Flintstonian times.

That would hardly be a fair assessment. Mature style is less limited by the kinds of media on hand than by the artist/craftsman's knowledge of the innate potentials of the materials and access to, and skill in using, appropriate tools. Even now, kindred materials are used on Earth to make sundry furniture items of premium quality, with a respectable market share.

But it is the absence of wood, organic and synthetic fiber, and plastics altogether as an option that will bring forth all the creative resourcefulness of the designer and craftsman in developing for the first time the full range of potential of the available materials. The results may be copied, or on the other hand anticipated, in the growing areas on Earth where wood is scarce, or more sorely needed for other purposes.

Combine this prospectus with the need to provide personal customized variety in what will for a long time be a very small market, and the challenge becomes stronger. One way to meet that challenge is to mass produce basic items in a simple functional design, "**issue**" (cf. G.I., government issue), that on the one hand has its own grace, and on the other lends itself to subsequent embellishment or elaboration, becoming a canvas, so to speak, for middlemen cottage industry artists and craftsmen, buying issue items wholesale and reselling them out of their homes or in streetside shops after they have been transformed under their skilled hands. Such items assuredly would be in great demand. Customers could buy "issue" items "factory-direct" for use as is, to give to a chosen artist for customizing on commission, or for do-it-yourself adornment.

Such an evolution of consumer product lines ought to merit real Frontier Government support. The brand new pioneer settlement culture, without access to the vast variety of manufactured goods available on Earth, will find in art/craft finishing of common ready to finish items an ideal way to provide the essential perk of custom individual variety. It is in the public interest to promote such development.

Once a "University of Luna" has been established, such art and craft activity aimed at making Lunan Homesteads more satisfying places in which to live, would appropriately become a major outreach concern aimed at full development of the widest possible range of Moon-appropriate art forms, materials, media, methods, and tools. Support for individual artists involved in this art/craft activity in collaboration with the University should extend only through the R&D phase. The market, expected to be quite vigorous, should be trusted to support mature expression in such newly developed Moon-appropriate forms.

What to make for furnishing the homestead from this burned out "cinder" of a moon? The "Cinderella Style" of the frontier will rise to the occasion.

FURNITURE

for the Lunan Homestead

by Peter Kokh

Furniture is commonly divided into three broad categories: 1) "CASE GOODS" include items commonly made of wood: bedroom sets, dining room sets, living room tables, desks, bookcases, etageres etc. 2)"UPHOLSTERED GOODS" are just that: fabric-covered and cushioned chairs, love seats, and sofas. Modern bedding, mattresses and box springs, would fall into this category. 3) "ACCESSORIES" include lamps, pictures and other wall-hung items, table top sculptures, etc.

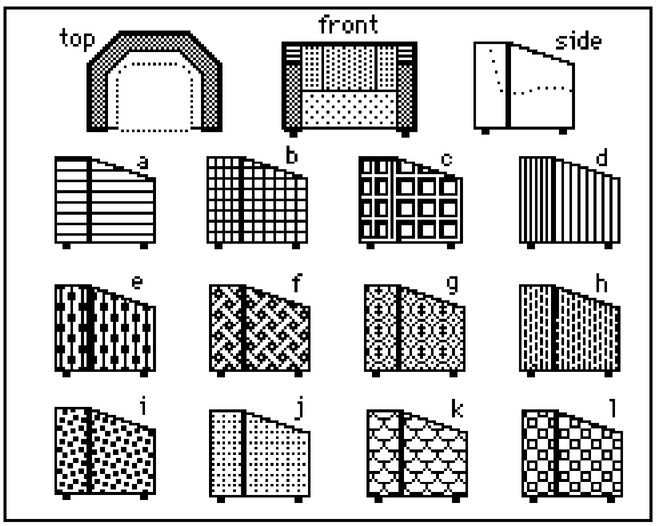
Metals have long been used for case goods, but their market niche has been narrow: office and patio furniture principally. Glass has been used principally for table tops. Ceramics principally for lamp bases.

Glass composites, the sleeper, has not been developed at all as a furniture item (or for any other purpose) but has enormous potential in superior serviceability and performance, as well as in visual appeal (cf. our previously published suggestion in MMM #16 JUN '88 "Glass Glass Composites" [Republished in MMM Classics #2] that a formulation in which the glass fiber is colored or stained and then combed within a transparent glass matrix to provide a material with all the "grain character" of wood, be pioneered for the high end furniture market in order to pay the high initial development costs of this new material. Glax, to use the suggested generic trade name, may lend itself to the same fabrication techniques as current fiberglass reinforced plastics. This means it should be suitable for molded contour fitting seating, as well as for structural framework, replacing wood.

Below we offer a number of product "studies", trial balloon designs of "issue" items that can either stand as is or be further embellished, all according to customer taste. (Recall that in the last issue, we predicted a turn away from the elegant simplicity of modern and minimalist styles towards more design-intense items as a psychological counterweight to the monotonous barrenness of the lunar surface surroundings.)

Cathedral Choir Style Box Chair, Love Seat, Sofa

In the illustration below, a glass composite molded seat and back, the actual "contact surface", is given an open supporting framework which can either stand alone or support encasing artcrafted panels of various types on the outfacing sides and back to provide a heavier, more design-intense piece. The variations shown do not correspond one for one with any specific possibilities, but are simply aimed at getting across the idea that an "Issue" item can serve as a "canvas" for further art and craft. The units could be ganged as modules to serve as love seats and sofas, either in look alike suites or in eclectic manifestations of the expertise of Lunan artists.



Among the many possibilities are:

◊ aluminum panels embossed and/or engraved
in abstract or pictorial patterns ("sculpsheet" alloy)
◊ textured metal panels including pyrited (fool's gold) steel
(brass or copper would be prohibitive)
◊ wire art
◊ wire weaves
◊ glass or ceramic beads strung on wires
◊ beads made from lunar rock
◊ macramé of fiberglass cords and ceramic and/or glass beads
◊ stained glass collages or murals
◊ glazed ceramic panels or tiles
of varying sizes, colors and mosaic patterns

Nb. If any of these seem "heavy", remember this is furniture for one sixth G or "sixthweight"

and for the softer look

◊ fiberglass fabric carpet
◊ fiberglass bands in multicolored scotch plaid weave
◊ fiberglass fabric pleated panels

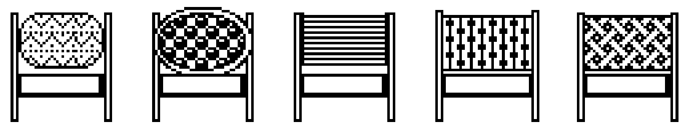
The vast variation in final appearances made possible by such a menu of possibilities yet maintains the common underlying shape of the parent "issue" item. Eventually, entrepreneurs would find ways to customize the lines of the piece as well, starting with the addition of decorative finials, head rests, hand grips, and swing-out foot rests.

Example: Chests and Dressers

A chest of drawers could consist of metal or glax drawers with a frontpiece frame to fill with matched or coordinated drawer front panels of choice, all in a metal or glax framework whose sides, top, and edges are again opportunities for optional embellishment. Drawer pulls of metal, glass, and ceramic add another avenue for variety. If in time it becomes acceptable to withdraw small amounts of wood at a premium price from the biosphere cycle, usual roles may be reversed: expensive wood handles and pulls adorning metal or glax chests, not metal and ceramic handles and pulls adorning wood cabinetry. Perceived value will follow bottom line expense.

Example: Bed Headboards

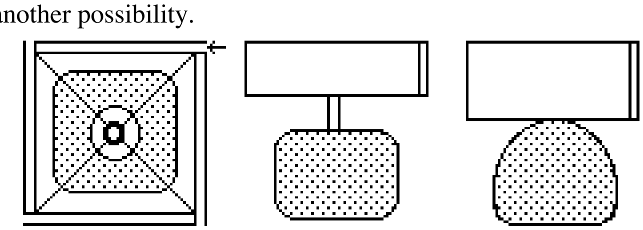
Rectangular, Oval and other Headboard frames could support similar "panel" finishing. A large variety of choices exist. And of course, we could have bookcase headboards with built in drawers and doors just as easily as on Earth.



Example: Lamp Shades

Lamp bases can be of metal, glass, glax, ceramic, or some combination of the above. Glass, glax, and ceramic will offer the greatest opportunity for coloration. Design possibilities are virtually limitless.

For shades, translucent parchment and fabric materials other than fiberglass will be unavailable. Translucent, not transparent glass shades are a likely favorite. But so are pattern- pierced metal sheet, possibly also embossed. Following suite, one "issue" item may be a simple framework for supporting various slip-in diffusing panels. Stained and waterglass/oxide painted glass shades have ample precedent. Pleated fiberglass shades will be most reminiscent of current favorite options. Glass beadwork and wire creations are yet another possibility.



Above are overhead and side views of a schema for rectangular metal channel framework "shade starters" ready for slip-in panels of various materials, designs, and colors. There is no attempt here to predict style lines, only to get across how "issue" items can support the search for individuality and personal expression, as well as a thriving community of artists and craftsman entrepreneurs, all learning seemingly trivial but psychologically important ways to make the lunar setting a fully humanized one.

UPHOLSTERY FABRICS

All this is interesting perhaps, but what about the need for visual softness, sound absorbency, and cushioning? We admit that we cannot be withdrawing vast amounts of natural or synthetic organic fibers from the Biosphere cycle, but ...! Available options are few: Fiberglass fabrics hold up well as long as they are left alone, i.e. abrasive contact is kept to a minimum. Thus fiberglass draperies, fiberglass wall carpeting, and fiberglass surround panels for box chairs, love seats, and sofas can be used to take care of the first two needs: visual softness and acoustic dampening.

As for cushioning, it is important to keep in mind that here in sixthweight the natural cushioning of buttocks, the soles of one's feet and elsewhere on the body should be quite enough especially when combined with contoured form-following molded seating surfaces. Underfoot, it would be far more effective and economical to put extra cushioning in shoe soles than waste it profligately on the floor at large. But again, in sixthweight, there should be little need.

Special needs: pillows and mattresses

Ahah! Solve that one! It's not all that difficult, really. The upholstered foam and/or innerspring mattress which we now take as a standard is a relatively recent invention. For millennia, humans managed to rest and sleep under much less pampering conditions. The bed of hay, leaves, or grass; the cot frame supporting a woven or canvas sling; piles of spare clothing; the web hammock, etc. On the Moon, almost any form of nighttime cushioning will require some investment of flexible organic materials. Our task is to find a solution which offers acceptable comfort in sixthweight with minimal use of organics. The air cushion mattress scores vastly higher here than the upholstered foam lined innerspring. But the cot sling may work well enough in the light gravity for a large segment of the population. The sling can be a fiberglass weave covered with a cotton pad. Cotton, the organic fabric with the lowest Moon-exotic content (being fully half oxygen by weight), will be both the least expensive and the most comfortable fabric in all uses "next to the skin".

[Cf. "APPAREL: Everyday and Occasional Made on Luna Clothing for the Early Settlement" by Peter Kokh in MMM #13, MAR '88 and "THREADS" by Aleta Jackson in MMM # 5, MAY '88. - both republished in MMM Classics #2]

For head pillows, an alternative to rolled up clothing would be the cotton slipcovered baffled silicone air pillow. Where back problems mandate, even in sixthweight, mattresses of similar construction would be the least costly choice.

To encourage prompt recycling of discarded cotton apparel and fabrics, there is likely to be a very generous cash-in value, if not a weight for weight trade of old and new goods. For those wealthy enough to snub such strong economic incentives, such things as braided bedside throw rugs and cases and fill for bed and sofa toss pillows can be made of unused clothing, bedding, and toweling. MMM

SCULPTURE

Making three Dimensional Art Objects from Lunar Materials

Perhaps most people, thinking of sculpture, imagine a piece of marble being chipped away by the sculptor's chisel in search for the form "lurking within." In this classic but very narrow sense of the term, Lunan sculptors may be left out in the cold. The kinds of rock favored for sculpture on Earth just don't form on the Moon where the geological processes are quite different. Perhaps some types of unfractured lava stone may yield to carving, but the crude results will likely never match those achieved in marble, granite, jade, alabaster, soapstone and other prized rocks and minerals. One lunar-sourceable inorganic synthetic, fiberglass sulfur composite, is an untried possibility. [See MMM # 65 MAY '93 p. 6 "MOONWOOD" Republished in MMM Classics #7]

But sculpture, in the sense of any three dimensional art object, can also be cast. Cast basalt and unrefined glass will be the first media available. Gradually, as chemical engineers do their work to produce needed elements and chemical feedstocks for Lunan industries, specially formulated pouring ceramics and refined glass will become available. As to cast metal, the traditional favorite, bronze, an alloy of copper and tin, will not be among the lunar-sourceable choices. Nor will copper, brass (copper-zinc alloy), pewter (tin-lead alloy), gold, silver, or platinum. Instead, only casting materials with much inferior "character" will be available: iron and steel, titanium, aluminum, and magnesium.

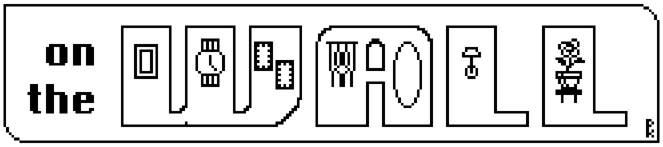
Metals, of course, can also be turned into sculpture by other means, principally machining and welding. Mold compacted and sintered iron fines may be suitable for some purposes. When it comes to welding, the lunar sculptor has an ace up his sleeve unavailable on Earth, the possibility of doing his craft outlocks where vacuum-welds may be achieved.

For cold-working, synthetic lunar clays made of hydrated aluminosilicates should be available fairly soon for the "potter". Lunacrete, lunar concrete, is another likely sculpture stuff. In both cases, all the associated water of the "plastic" or "green" body is eventually released to the biosphere's atmosphere, to be recovered by dehumidifiers. Gypsum plaster or plaster of Paris, however, must retain water of hydration and so will be an expensive option, without compensating quality.

Sculptures are also carved from organic materials such as wood and bone (ivory and scrimshaw). On the Moon, it is not likely the latter will ever be available except as heavily taxed imports. Wood will be so precious that it may well be a prestige jewelry stuff. In effect, good carving woods, perhaps derived from fruit trees, e.g. cherry, apple, pear and others, will share the niche now owned exclusively by gemstones. These in turn, except for synthetic corundums (a form of aluminum oxide) like sapphire and ruby, may not be found on the Moon.

In a broad sense, sculpture can also be "composed" by mechanical assembly. Metal parts, sheet, or wire as well as moon rocks like breccias could be used in this way.

The options are different, and fewer. But the Lunan sculptor will still produce creations of beauty. MMM



Part II: What to hang?

"Paintings"

As mentioned last month, LRS is sponsoring an effort to pre-develop a line of lunar-producible sealants, paints, and stains all based on Waterglass, sodium silicate hydrate, a liquid and the only known inorganic adhesive. We cannot predict results of our experiments and perhaps we will quickly reach some showstopper. But we have identified a local source of waterglass at only $10/gallon, and we do not anticipate much difficulty in finding local sources of lunar-producible metal oxide powders to use as tints and pigments. A tentative agenda of experimentation has been worked out but this will change, perhaps drastically, as we see how our concoctions behave. Meanwhile, let's assume sufficiently favorable results to support fully lunar-appropriate painting art and craft.

The first thing a painter needs after his/her paints of course, is something to paint on. For wall hung art, that means a **canvas** of sorts. Among the lunar-producible, inorganic substitutes for common canvas that come to mind are:

◊ opaque glass (front-painted)
◊ ceramic tablet or tile
◊ metal sheet
◊ stretched, waterglass sealed fiberglass fabric

Nb. if this application is brittle, then the fabric may need to be stretched over glass or metal support sheet, not just stretched over a hollow frame.

◊ back-painted clear glass
◊ back-painted unbreakable glax (glass glass composite)
◊ vitreous glazes on a ceramic tablet, or tile mosaic

For mass production, once a master has been made or designed (on a computer), computer run machine produced art is a possibility. But given the small market and the need to have something different from the Joneses, the market share for items like this seems small except for cliché paintings of the Earth, settlement site panoramas, and a few other subjects.

Next the painter (or the gallery) will want a **frame**, and possibly **matting**. Glass, Glax, ceramic, and metal frames are possible and may well be mass-produced in stock sizes with pre-drilled top-center hanger holes. Besides the common flat frames, there could conceivably be exterior hull wall contour-following cylindrically or spherically convex frames and canvas substitute painting boards, as a specialty item. Fiberglass fabric covered metal strips in stock sizes may do for matting.

Pictures and Portraits

Portraits may be "painted" using the methods and materials suggested above. They can also be etched on glass or metal, or beaten, *bas relief* style, in a malleable metal sheet. **Photographs**, however, are a more problematic subject. Cameras will likely be expensive "upports" from Earth for a long, long time. Ditto with film. You can *choose* to think the settlers will be affluent enough to make Earth-style photography as common a hobby on the Moon as it is here. I think not. Perhaps a few who do weddings and other special occasion work could make a go of it, but their fees and prices will have to be quite steep. What about a lunar solution? Film substrate is one problem, photosensitive coatings are another (you can forget about silver). If inventors and entrepreneurs could come up with some ingenious lunar substitutes or hybrid lunar-terrestrial solutions intermediate in price, then "standard" camera cases could be locally produced of metal or Glax, to be fitted with optics assemblies upported from Earth, a so-called "MUS/cle" solution. This is really the topic of another article, and yes, MMM is looking for a volunteer to do the research, or assist in doing it. Anyone?

Other wall hung items:

Ceramic and **cast basalt** bric-a-brac items should be fairly inexpensive, depending upon the glazes and special art finishing used. Glass and/or ceramic **Beadwork**, American Indian style or other, using woven fiberglass threads or thin wire, should reach a new popularity. **Macramé** using similar materials with fiberglass cords, or conceivably rescued twine used in packaging sundry items shipped to the Moon, could be another standby.

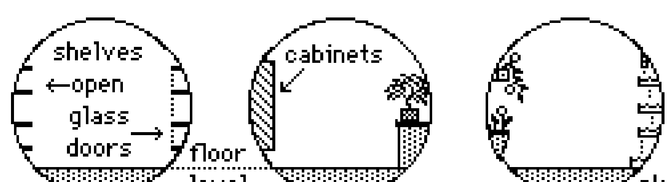
An **aluminum** alloy can replace copper as a medium of wall hung **metal sculpture** and bas relief work. **Wire Art** creations are another easy medium.

Fiberglass tapestries, perhaps with embroidered panels using fiberglass threads of various color stains may be possible. However, fiberglass threads are rather brittle compared to cotton and nylon, as well as potentially irritable to the hands of the artist. Experimentation to devise workable methods for such a craft will be needed.

Stained glass art panels suggest themselves, but do take note of one problem. The caning in universal use to create the cartoon lines of common stained glass mosaics is made of lead, which is most unlikely to be available except at a very dear price. Are their other lunar-producible sufficiently malleable alloys which can be used? Or might the artist bond the individual pieces to a piece of clear substrate glass, perhaps using sodium silicate as an adhesive?

Wall lamps, sconces and wall washers with glass or metal light diffusers or shades should be common enough.

Knickknacks, **shelves** and shelving could be made of metal or Glax (glass glass composite). Some wall-hung curio, display, and other type cabinetry and shelving systems may be custom designed to fit the middle height range of the convex hull shells of the various habitat modules.



Wall hung **planters** of metal, ceramic, or Glax, even **fountains** and water cascades may adorn convex or flat walls.

In short, Lunan Homesteads may be as rich in wall-hung items, both functional and beautiful, as homes Earthside. The choices will be meager at the start, of course, but quickly expand as entrepreneurial art and craft cottage industries spring up, their creations sold in weekend streetside bazaars.

"Art du Jour"

Temporary Creations of Lunan Settler Children made of organic craftstuffs from farm & garden and meant, with rare exceptions, to be recycled

Relevant Readings from back issues:
[Republished in MMM Classics #3]
MMM # 22 FEB '89 p. 6 "HAIR"
MMM # 26 JUN '89 p.4 "TOY CHEST"
[Republished in MMM Classics #4]
MMM # 34 APR '90 pp.5-6 "The Fourth R"

To foster artistic talent in the young, it is important to supply them with "play-media" upon which to exercise their talents. For this purpose, organic stuffs derived from garden and farm might be permitted a short-term detour en route to their recycling back into the biosphere via biodigesters or other routes. Natural dyes can serve to develop painting talents upon easy-to-recycle simple recyclable papers. Potatoes and bars of soap can help develop carving talents. Beeswax and putty made of flour, water, salt, and baking soda can stir in them the talent of the potter. Corncobs, husks, seeds, kernels, nuts, eggshells, peanut shells, bones and even hair clippings are things with which to make dolls, toy characters, and other "neat stuff".

Parents proudly display their children's creations, and often put them on display where they will be noticed by any visitors. But save for exceptional samples, most of these loose whatever encouragement value they may have rather quickly, given youngsters' usual swift progress. They can then be recycled back into the biosphere, having served their purpose. Eventually, those who have displayed talent worth encouraging further can be weaned from these media, graduating to the inorganic art media that can be supported by the settler economy, reliant on local resources.

In addition to organic stuffs for "art of the day" creations, school students may have access to sundry other items at the start of the recycling pipeline. Sculpture made from scrap metal, glass, ceramics, and other inorganic materials, if prizeworthy or salable, can be left intact permanently with little or no ill effect on the economy.

And if, as we've suggested, older children are charged with the creation and production of toys for younger ones, this may develop their entrepreneurial talents as a bonus. MMM

Homestead Furnishings & Decor

COTTAGE INDUSTRY

As we suggested in MMM # 75, one of the reasons to build settler homesteads in a generously pre- expanded form, (the concept of the Great Home) is to allow room within for the birth of cottage industries. In the early settlement period, the worktime services of almost everyone will be needed to support the biosphere (food production, recycling, etc.), export trade, and manufacture of basic needs (shelter, some basic furnishings, "issue" clothing, etc.). The need to reach real economic break-even and then go on to economic profitability i.e. a positive trade balance with Earth, *as soon as possible,* will be *the* governing fact of life for a long time. To the extent that this condition still prevails, the only labor available for the creation and production of "luxury" items, from personal touch clothing to customized furniture and art- and craft-rich furnishings,,, will be the spare time after hours of those who have both talent, leftover energy, and the entrepreneurial soul.

This activity deserves to be supported because the morale of everyone stands to benefit. One way to effect this would be for the settlement government to "subsidize" the import of special needed tools to be owned by *cooperatives* of artists and craftspeople on a time-share basis. The individual cooperatives, or even a union of cooperatives, could schedule training classes in tools, materials, methods, marketing, joint ventures, etc. A publicly owned complete library of terrestrial folk and ethnic arts and crafts of all types would serve the settlement well. For many such historic arts and crafts may prove to be inspiring models of resourcefulness.

Once a "University of Luna" has been established, an Extension Service to Cottage Industries ought to be an early priority. For today's cottage industry serving local needs may someday grow and evolve into tomorrow's exporter. Surely such cottage industry will be a prime wellspring of economic and industrial diversification.

This is not to ignore the harsh fact that the transition from home-nested spare-time moneymaking hobby into a true independent small business is difficult and fraught with risk. Again, government and university services should be available to help those willing to take the plunge. Others will be content to continue operating as a part-time at-home hobby for fun and spare change, and they should not be discouraged. MMM

[Pioneering a Moon-appropriate art medium]

WATERGLAZING

R&D Report: #1 — 6/22/'94

As reported in last month's MMM, an LRS-supported project to attempt to develop a lunar-appropriate "painting" medium has indeed begun. The seminal idea arises from the fact that waterglass, a hydrated sodium silicate (and a chemical cousin of ordinary garden variety window glass) is the only known inorganic adhesive.

There the idea lay, germinating, for several years until last May 3rd when we learned that a local Milwaukee pharmaceutical supply house, Laabs, carried sodium silicate for $10 a gallon. When shortly after that MMM received a $50 donation from Glen P. Wilson, NSS Executive Director Emeritus, the LRS board agreed that this ground-level R&D project would be a fitting place to invest it. Peter Kokh is the experimenter.

Purchasing the needed materials

On June 16th, we bought a gallon of sodium silicate. We applied some, as is, with an ordinary brush, to a brick, a terra cotta flower pot, a glazed pot, and to pieces of glass, aluminum, and sheet metal. The brush cleaned easily in water. The waterglass dried within an hour on all items, beautifully varnishing the brick and the terra cotta pot. It “skipped” somewhat on the metal and glass surfaces but still had a high gloss.

The next day, we took the sheet metal piece and put it under a stream of warm water, rubbing vigorously. The Waterglass “varnish” dissolved and washed away. On the other hand, we sprayed the glass piece with Windex and wiped it clean, with no apparent loss of the “waterglaze”. This would seem to place some limits on its usefulness, but limits we could live with. For example, if the home had “trimwork” around doors and elsewhere of unglazed ceramic tiles, these could be water-glazed. When dirty from hand soil, they could be easily washed clean and reglazed. Meanwhile, art objects painted or glazed in this medium, and safely out of harm’s way, should endure indefinitely, even with occasional gentle cleaning.

The next day, we baked the aluminum sample in a 250° F oven for about half an hour. The waterglass lost its glossy appearance and “crystallized” to a whitish color, still adhering firmly to the substrate in the pattern in which it had been painted. The effect seemed rich in its own right, and suggests that metal might be decorated with either “baked” or “unbaked” waterglazes. Baked on the reverse side of glass, the effect is rather reminiscent of glass etching.

So much for the first round.

Our plan is now to get some colored metal oxide powders and start mixing. Different mix ratios will be tried for each oxide and the effects noted. In addition we plan to apply plain unmixed waterglass to various substrates and then sprinkle oxide powders on them, in effect “flocking” them, in various patterns. And we intend to bake some of the results.

We would also like to find lunar-producible inorganic powders which prove soluble in waterglass in addition to those forming suspensions. We’d like to come up with a serviceable spectrum of hues in both opaque (paint) and transparent (stain) varieties. We intend to religiously avoid any organic additives, dopants, or pollutants of the product preparations.

So far, while only the first step has been taken, the results are rather encouraging, our instinctive hunch verified. Our long term goal is to produce “Waterglazing Kits” to sell (at a modest markup to enable further experimentation) to those with *real* artistic talent. It is only in this way that we will see what this new infant art medium is really capable of producing “in full flower”. Sponsored competitions timed with the annual ISDC would be helpful in supporting such an outcome.

While our ultimate purpose and ulterior motive is to put “on the shelf” a ready-to-go lunar-appropriate art medium with which artistic settlers might humanize their homesteads, we fully expect some terrestrial artists to make real money selling their waterglaze creations near term on terra firma.

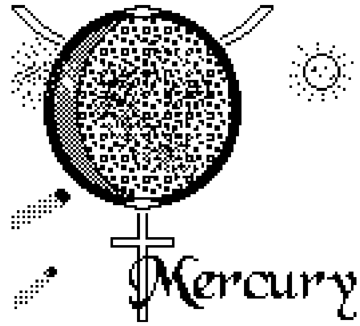
If you would like to participate directly or indirectly in this “colorful” little R& D project, please call or write:

Peter Kokh
1630 N. 32nd Street
Milwaukee WI 53208-2040
(414) 342-0705
kokhmmm@aol.com

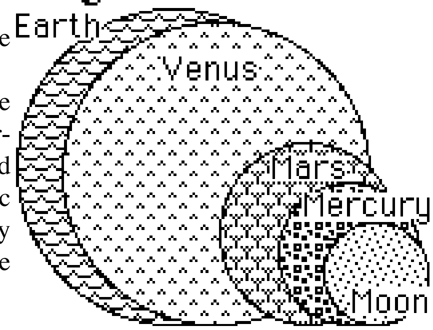
Additional donations cheefully accepted! Please make payable to LRS but note on the memo line that your donation is for the “Waterglass Project”. **PK**

MMM #78 - SEP 1994

Mercury and “location, location, location”



Mariner 10 - at first blush - showed Mercury to be a duller albeit larger version of the Moon. It takes a lot of Delta V (i.e. fuel) to get there, and is unpleasantly hot. The fact that all we can see is minuses, with *no* redeeming pluses, should alert us to the likelihood that we are looking at Mercury from the wrong angle.



With a daring change of perspective, this forgotten, spurned world reveals strong strategic pluses. One article by Michael Thomas, one by Peter Kokh.

Mercury

THE *OTHER* TERRESTRIAL PLANET

by Michael Thomas, MMM Contributing Editor

As a result of the recent discovery of polar caps on Mercury, presumed to be composed of water ice, the innermost planet is a much more exciting world than it was before. It is also a much more likely target for possible human habitation, as there are now known to be two small oases of cold on this world of unimaginable desert heat. We know there are places on Mercury where a craft could land without having to insulate itself from the searing heat and radiation of the nearby sun.

Are these polar caps really made of water ice? There is a possibility that they are not, but a more recent radar study of Mercury seems to confirm that their reflection pattern is consistent with what would be expected from water ice. I think it would be fair to say that there is an 85% probability that Mercury's polar caps *are* water ice. But even if they are not, these oases of cold would be far more habitable than any other part of the planet's scorched surface.

In the past Mercury has been dismissed or overlooked for a variety of reasons. It is too far from Earth, too close to the Sun, and much too hot. Solar radiation is almost seven times more intense at the surface of Mercury. There is no appreciable atmosphere to shield out the more intense and harmful ultraviolet rays. Mercury has been visited by only one spacecraft, Mariner 10, which photographed just half of it's surface. The other half is still *terra incognita*. It is the only terrestrial planet so neglected.

But Mercury offers compensating advantages all the same. Although it is only about half as massive as Mars, and it's diameter is only 71% that of Mars, the two planets have almost identical surface gravities. For Mercury has a higher average density than Mars because of its much larger iron rich core. So although it is the smallest of the terrestrial planets, it's surface gravity is suitable for human habitation.

Mercury also possesses a planet wide magnetic field. There is some limited evidence that terrestrial life requires the presence of a magnetic field to thrive. (Mars may also have a planet wide magnetic field, but if it does it is weaker and less likely to be biologically significant.) Mercury's proximity to the Sun offers advantages as well. If Helium-3 is to be found in the lunar regolith, surely even more of it is to be found in the regolith of Mercury, which is closer to the source. And with solar energy being almost seven times more concentrated in the orbit of Mercury than in the orbit of Earth, there is a wealth of energy too great to be ignored.

The average intensity of solar radiation at Earth's orbit is 1390 watts per square meter. At Mercury it is 9271 watts per square meter. This has a curious result. A square meter of solar cells in Earth orbit, operating at 15% efficiency would produce 208 watts of power. The same solar cells in Mercury orbit would produce 1390 watts of power! In other words, moving the solar cells from Earth to Mercury has the same effect on their output that increasing their efficiency from 15% to 100% would have. This makes the vicinity of Mercury a far better place for Solar Power Satellites than Earth orbit. A one terawatt collector (operating at 15% efficiency) in Earth orbit would have to have 4,807 square kilometers of solar cells, but a one terawatt collector orbiting Mercury would only need 719 sq. km. of solar cells.

And how better to support the power needs of a terra-watt laser than with a terawatt solar array. Such a collector would be far cheaper and less massive in the orbit of Mercury than it would be in the vicinity of Earth. A pair of terawatt lasers located in the Mercury/Sun L4 and L5 positions could also be directed at a solar array in high Earth orbit as a means of exporting energy to Earth. They could probably maintain near continuous transmission to Earth as they would never both be behind the sun at the same time. Mercury could also be a base for launching power satellites closer to the Sun, where they could collect even more energy.

Yet Mercury offers more than just a base for solar power collection. Just as small island nations like Japan, Great Britain and Taiwan support populations of millions, so the polar oases on Mercury and the immediate surroundings could also support populations of millions of people each, making Mercury a significantly populated world. Areas just outside of the permanently shaded oases would receive intense sunlight, but at a very low angle, so regolith temperatures would be much lower in the daytime than at lower latitudes, so these near-oasis areas would be relatively habitable as well and could be used to collect solar energy for the communities within the oases. In the long term (centuries) the higher latitudes (above 70 degrees perhaps) could be widely inhabited with each pole supporting perhaps 100 million people.

So while Mars is more accessible and more hospitable than Mercury overall and should be the next planetary destination for humans after the Moon. — Mercury should not be dismissed and forgotten. We should begin to view Mercury as the third planetary target for human habitation after the Moon and Mars because this scorched little world really has much to offer! MT

Why hotter Mercury may have polar ice while the colder Moon may have little

by Peter Kokh

AVAILABILITY: It is quite clear that fewer comets intrude into the deeper regions of the Sun's gravity well where Mercury orbits than visit the orbit of the Earth-Moon system.

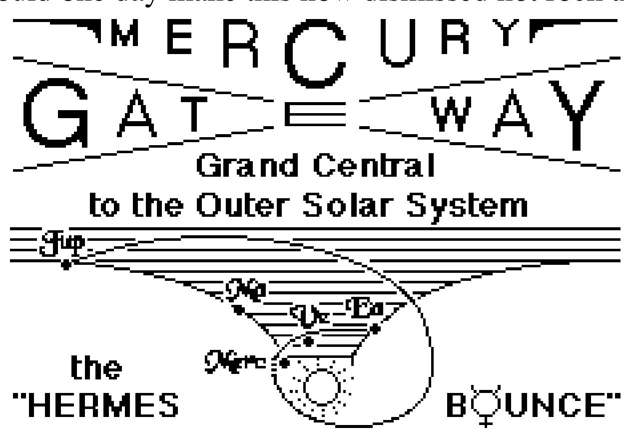
HOWEVER: Mercury may be much more effective in snaring approaching comets than the Moon. Mercury's mass is 5 times that of the Moon. Further, its deeper gravity well presents a much greater "cross section" expressed as an angular fraction of its orbit, in fact a "target" comparable to Earth's, some thirteen times as great as that of the Moon.

FURTHER: Two factors work together to make Mercury much more efficient in holding on to cometary volatiles.

√ Mercury's gravity is 2.3 times that of the Moon.

√ Its sun*set* to sun*rise* "nightspan" period is more than 6 times longer than the Moon's, giving volatiles released by comet impacts that much more time to migrate to the polar permashade cold traps.

The intense solar power available in Mercury's orbit could one day make this now dismissed hot rock the



by Peter Kokh

For Science Fiction, there has never been a problem with opening up the outer Solar System. Its "simply" a matter of inventing faster rockets, atomic ones probably. In point of fact, Mars represents the limit of "doability" of the venerable chemical rocket for crewed expeditions. No plausible improvements will extend this margin in any practical sense. Chemical rockets cannot carry enough fuel to take expedition-sized payloads much further. More, maximum efficiency travel times in Hohmann transfer orbits (without which chemical rockets could not even take crews to Mars) mean many months in space and unwelcome total exposure to solar flares and cosmic radiation.

Nuclear rockets are still largely on the drawing boards, but promise faster trips to Mars, doable trips to the Main Asteroid Belt. But even for them, trips to outer planets may be unacceptably long, ... and infrequent. For any vehicle must await proper planetary orbital alignments - the “window”.

Some Trip Window Frequencies (bidirectional) and average Hohmann travel times (both in 30 day months)

between		window frequency	travel time
Earth/Moon	**Mercury**	**3.45**	**3.51**
Earth/Moon	Mars	25.87	8.63
Mercury	**Mars**	**3.36**	**5.68**
Earth/Moon	Ceres	15.55	15.75
Mars	Ceres	38.67	19.13
Mercury	**Ceres**	**3.09**	**12.01**
Earth/Moon	Jupiter	13.30	33.27
Mars	Jupiter	27.21	37.56
Ceres	Jupiter	91.81	48.43
Mercury	**Jupiter**	**2.99**	**28.36**
Earth/Moon	Saturn	12.60	73.65
Mars	Saturn	24.46	79.20
Ceres	Saturn	66.56	92.96
Jupiter	Saturn	241.9	121.8
Mercury	**Saturn**	**2.96**	**67.33**
Earth/Moon	Uranus	12.33	195.2
Mars	Uranus	23.42	202.8
Ceres	Uranus	59.47	221.4
Jupiter	Uranus	168.1	259.2
Saturn	Uranus	550.5	331.6
Mercury	**Uranus**	**2.94**	**186.3**

Anyone who studies this list should quickly get the idea, that, Delta V and fuel cost aside, The quickest way to get from anywhere *to anywhere else* in the Solar System might be to “detour” by Mercury. What about alignments? So what if you get to Mercury and have just missed a window to Jupiter. Another will open up in just 3 months, an insignificant delay parked in Mercury orbit.

Ah, but Delta V and fuel cost do matter, you say! My point is that much of the extra Delta V needed to do the detour by way of Mercury can be managed by free deceleration into orbit around Mercury, and free acceleration into a trans destina-tion trajectory — free courtesy of giant solar lasers in orbit about Mercury.

In going to Mars or Ceres this presents a problem. The Mercury-boosted ship will arrive with a great deal of excess momentum. This will require a lot of fuel to shed. But ships going out to any of the moons around any of the Outer System gas giants, can shed that excess momentum *free* in an aerobrake maneuver through the upper atmosphere of the gas giant (Jupiter, Saturn, Uranus, Neptune). In fact, the only Delta V that need be provided for by fuel carried on board is that for the boost in *toward* Mercury, and the landing fuel at the destination moon that would be the same in either case.

The benefits would be astounding

LEAVE ANYTIME and
GET THERE MUCH MUCH SOONER.

Building such a giant laser facility near Mercury would be something for a “United Planets” government. It would establish singlehandedly a transportation infrastructure that will open the gates of human expansion into the Outer System, in search of energy (e.g. Helium-3 from Uranus), the ultimate in tourist experiences (Saturn’s rings), raw materials for terraforming (water, hydrogen, nitrogen, carbon), and exploratory knowledge.

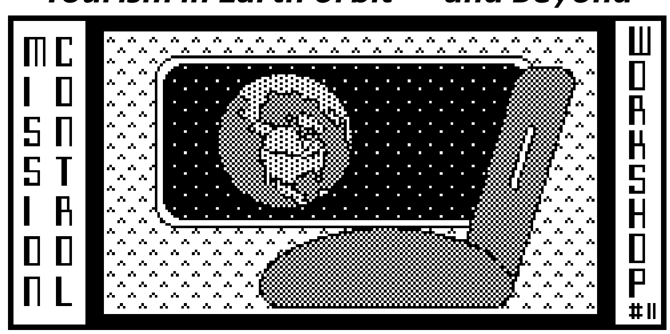
Because ships arriving at Mercury will have to wait up to 3 plus months for a reboost to their destination, there will be a major service market in orbit about the planet. This will include ship repairs (engines, environmental systems, bio-sphere systems), warehousing, trading, transshipments, health care, entertainment and diversion, surface excursions and stays, even continuing education courses. And all the more interes-ting things that are usually found in wide open international marketplaces. Mercury Gateway could over time grow to become the nerve center, financial center, trading center, even the political center of the Solar System.

Yes it’s hot!, Yes it’s dry! Yes it’s barren! But so what! Mercury’s location deep down the throat of the Sun’s gravity well and its location in very bright space (averaging seven times as much light and heat from the Sun as reaches Earth/Moon) — these are the real estate pluses that will make this unsuspected oasis in the solar desert bloom and boom.

First, of course, nuclear rockets will have to come on line, and mature. Next, economic motives must surface that would drive the expansion of the human economy into the Outer Solar System. Finally, some taxing authority has to build the necessary facilities in Mercury orbit. Then this “god of speed” will be not only speedy himself, but impart some of that swiftness to us mortals and our “Quicksilver Fleet”.

Mercury, it’s a detour that makes sense! ***PK***

“Tourism in Earth Orbit — and Beyond”



May 28th, ‘94, ISDC ‘94, Toronto, Ontario
Led by Peter Kokh, Mark Kaehny, George French

Part 1: *A Space-going Tourist The First Flights*

Mark Kaehny, President: LRS, Editor MMR
Team: Ronnie Lajoie, Ruth Petra, Morrie Schneiderman, Mark Kaehny (discussion leader and secretary)

Tourism is perhaps the largest "industry" in the world at present. People like to see new sights, try new things, be thrilled, and of course show off their wealth and status. If we are to expand our human experience off the Earth we will also have some of the most exciting, spiritually uplifting, and expensive experiences accessible to those who want to try them.

In this workshop exercise we tried to explore what the first steps in Space tourism might look like. We defined space as in the IAU definition of 100 km (not 50 miles like the US Air Force). Thus the "space" part of space tourism means going at least 100 km (62 miles) up for some period of time. The group considered a time of a few minutes to a few hours as the period in space. "Tourism" generally means going somewhere or doing something for personal enjoyment and the experience.

The Current "Space Tourist" Options

Currently there is only one possible Space Tourism opportunity - the Russian Space Program if you have enough cash (say $10 million). This is not guaranteed but it currently is the only game in town.

There are several other opportunities at present for the adventurer that have some relation to space. They may go to Space Camp™ in Huntsville, Alabama and work through a simulated shuttle mission. They may experience micro-gravity in several places for a period of time longer than the nearest rollercoaster - aerospace companies or organizations off parabolic flights with several minutes of weightlessness in Russia and commercially in Idaho. If you can fake being "useful" (remember we are talking about a tourist here!) you may even get on NASA's micro-gravity plane. These experiences cost from several to many thousands of dollars.

The only truly commercial one of these enterprises is Weaver Aerospace in Idaho. Commercial in this case meaning that the Company is not just scrounging equipment built for other purposes and making extra money, but rather that this is their business and the proceeds are put back in to the company. Actually Interglobal Space Lines, Inc. (307-739-1296) provides the flight opportunities through Weaver to Tourists.

The closest the "average" millionaire can get to space now is to get a ride in a Mig 25 up to 15 kilometers or more. At this level one must wear a pressure suit, sees the stars with the eye in sunlight, and sees clearly the Earth's curvature. This kind of experience costs tens of thousands of dollars. (If you don't already live in Russia.) There is a steady supply of people doing this. So where do we go from here?

The Next Generation

What can a tourist look forward to in the next 10 to 15 years and what kind of market will there be at various price levels? Our group concluded that tourism could actually be a driving factor for development of maneuverable suborbital spacecraft designs and also for orbital designs.

For true "space tourism" we assume that one or several of the Single Stage to Orbit designs works. The "sortie" cost of a flight has to be brought down to between $100,000 to $1,000,000 depending on the number of passengers. This would seem to be a necessary prerequisite for space tourism. This market segment includes those people who do the activities described in the previous section and people that go to the Antarctic, who make scuba trips, who take helicopters to ski down Greenland slopes, etc. The common denominators are a willingness to take a chance to get a unique experience, and the ability to pay for it. A "space experience" including a suborbital flight (or depending on launch prices a few-orbit-flight) was assumed to cost $50,000 or so. This was just taken as a figure out of the blue - launch costs have to come down by an order of magnitude for something like this to be possible. No market surveys were done at this point. The group decided to concentrate on fleshing out what a tourist would be buying when they bought a "space package", what kinds of equipment would be needed, and a 'walk through' of what the experience might be like. Sooner than one might think, people will routinely fly into space, just for kicks.

What a Ticket Might Buy

Suppose Jane Doe buys a ticket from Space Tours Inc. What is she going to get? Certainly not just a quick one hour flight for her $50,000 dollar ticket! The experience should be a combination of Space Camp, Emergency Rescue training, and an American Museum of Natural History Cruise. Jane would pick a 2 week period for her trip. She would come, have a flight physical to qualify her (before paying, of course), and spend about a week in orientation which may include a micro-gravity flight in a plane. Also for some types of suborbital flights she may need to worry about high-G stresses. The orientation would consist in getting familiar with the cabin environment, and if Space Suits are to be used, with her suit and how it works.

Since the tourist company would want to maximize throughput of people, part of the orientation would be given by people who have already been on the flight. This allows for socializing, and for letting the "experienced" show off a little. Depending on the kind of flight, different things would be emphasized. As with things like Space Camp, each person would have a personal video of how they trained, and how they taught.

For a suborbital flight lasting on the order of Alan Sheppard's flight [i.e. about 15 minutes] it would be nice if the craft could return to the point of origin. This means cross range and some kind of maneuverability in the vehicle. There would be at least 10 minutes of weightlessness. Flight problems that would have to be dealt with are sickness, panic, normal bodily functions ... and room. To deal with these there would have to be "caretakers", more than just stewards and stewardesses, along. These people would have to be able to deal with unforeseen problems. Diapers [chux] of some kind or a similar system could be used for as short a flight as this. Room is certainly important.

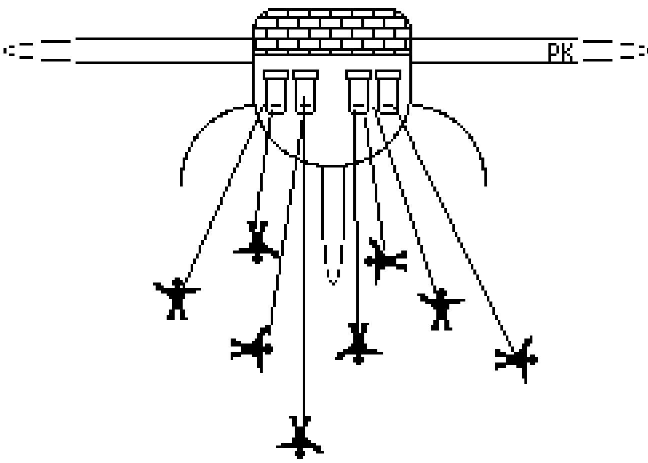
If you are crammed in a little space with no window you won't even notice you flew! Large windows and some room, perhaps as much as is given in a railway seat (bigger than an airplane seat), would be nice [although such generosity would surely increase ticket prices - Ed.]. The spacesuit option discussed below is probably impractical for this short a flight. Either everyone will have their video equipment or cameras, or overall video would be provided. The flight schedule should be such that either a sunrise or sunset would be visible to the passengers. A little night Earth viewing would be nice.

Orbital Flights

For an orbital flight, with more than an hour of micro-gravity more problems (and more fun) are possible. This could be a LOT more expensive than suborbital flights.

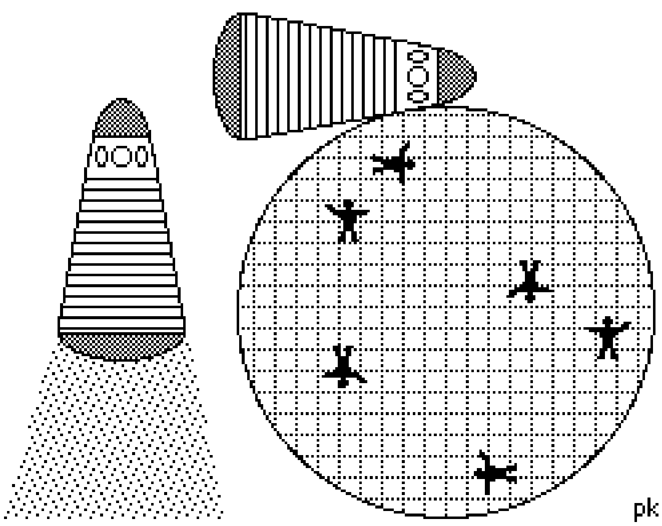
One option discussed was the idea that each passenger wear a space suit, and that the cabin be opened up so that each ticket-purchaser could float in space, for a true “in-space” experience.

Points to consider would be the design and manufacture of relatively inexpensive space suits, and the probable need for extra personnel to deal with people getting sick in their suits, etc. One could just have the top of the cargo area open up above the people, people would be hooked to their seats by short lines so they wouldn't get tangled up, but they could mess around. Another way is to have the people exit a hatch on some kind of control structure.



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

Finally, there was the suggestion that a strong but practically invisible net be cast out as the cabin doors or roof opened, so that each passenger could float truly free, without tethers and tether entanglement problems. But then how would you round everyone up? Sooner or later the romp must end so as to start making preparations for a descent out of orbit.



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

With Spacesuits would come the need for radio communications. What if somebody becomes disoriented and starts screaming? The caretakers should be able to cut off people from the general circuit. Depending on the number of passengers, there may be several circuits for people to use. Spacesuits or helmets would be uniquely labeled, different colors, etc., for easy identification. Depending on cost, the passengers could have the option of keeping them. Problems with the spacesuit approach are obvious and the danger would be greater, but what an experience!

Other possibilities for orbital flights would be the ability to call friends and relatives on the ground from orbit, and all the viewing described above. With orbital fight, everyone will get to see at least one sunrise and one sunset. The craft should also return to the departure point for more centralized operations.

Note that this is the report on an "idea generating" exercise in thinking about this type of tourism. The problems were not dealt with in detail; rather the idea was to get some feel for the experience. It would be dangerous, some people would die, but people die every year scuba diving. The people to whom space tourism would appeal would not be risk averse.

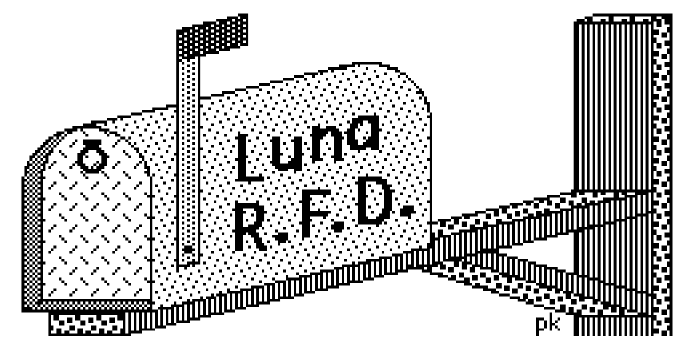
Space tourism of the sort envisioned is dangerous but perhaps NOT as physically demanding - an older person (>65) in the group was quite interested. The existence of groups like Weaver Aerospace and Interglobal Space Lines makes us hopeful that this kind of thing will come about, and point the way for what kind of space research NASA could be doing -- developing the engines, designs and test vehicles, so that the type of spacecraft needed for these flights would be available!

MRK

Vision without action is just a dream
Action without vision is just activity
Vision and Action together can change the world.

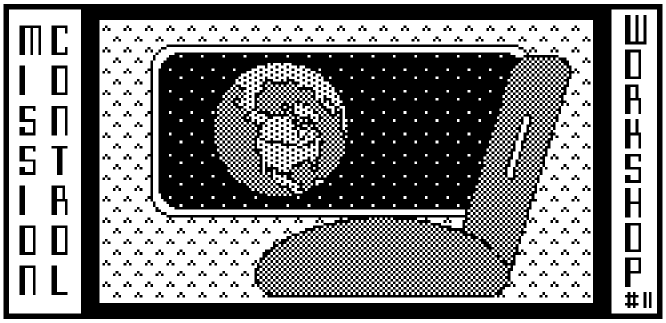
MMM #79 - OCT 1994

MMM begins a New Series



On the face of it, the expression “Rural Luna” sounds a bit tautological (like the hot Sun, or wet water). But once there is a permanent outpost or settlement, a very sharp contrast will assert itself between the *relatively* civilized human enclave and the rest of the Moon’s barrenscapes. Using the initial outpost as a Base Camp, secondary visited, camped, tended, and staffed sites will find there way onto the map here and there. Mining operations, science outposts engaged in geology and astronomy, tourist stops, and eventually secondary settlements will come as the humble human beachhead slowly phases into a genuine global presence.

"Tourism in Earth Orbit — and Beyond"



May 28th, '94, ISDC '94, Toronto, Ontario

Led by Peter Kokh, Mark Kaehny, George French

Part 2: The first Space "Hotel":

Aiming at a ready-made market

George D. French, Jr.
President: Wisconsin Space Business Roundtable.
Wisconsin Delegate Aerospace States Association

TEAM: Richard Richardson, Edward T. Reber, Kyle Smith, George French (discussion leader and team secretary)

While the suggested "Mission" of our group was to "assume an operational Earth-to-Orbit Passenger Vehicle of some type and design an i*ndependently orbiting* minimal tourist hotel *not attached to a Space Station* and suitable for stays of a few days ..." we decided on a much more conservative and practical project. Our reasoning was that *business and industry travelers to the station* would form the first hotel market, not private individuals going up for personal pleasure.

Accordingly we endeavored to define this ice-breaking market niche, and then define just what kind of a facility, *attached to a space station,* might fill their needs.

At the time of the Toronto ISDC last May, the future of "Ralpha", the proposed joint Russian-American Mir II based station was still in doubt. Its proposed inclination of 51˚ to the equator, fine for Earth observation of temperate latitudes seemed to us less than ideal in that it made access from U.S. spaceports (European, Japanese, Chinese too) more difficult and expensive. The scenario we were working with was a multi-government built station in a 28˚ to 32˚ orbit, a compromise between accessibility from most international spaceports and the range of observable latitudes.

Attachment to an oft' proposed commercial orbital facility seems another option. If both types of facilities exist, cooperation between them is likely, depending on their mutual proximity in orbit If Ralpha is built as proposed, the appeal of and incentives for a second commercial station in a much less highly inclined orbit (better as a staging point for deep space operations of any sort) would grow stronger.

The advantages of attachment to an existing station, government-run or commercial are these:

√ there will be a ready-made market for housing commercial, industrial, and official visitors to any existing station engaged in orbital research and/or manufacturing.
√ Power, communications, and attitude control, and orbital altitude maintenance would be already provided for by the host facility, making the hotel more of an "incremental" expense, much more feasible to amortize with (company or government-paid) guest registrations and thereby more apt to earn a profit. We think it makes more sense that any such facility, even attached to a multi-government international facility like the defunct Freedom or current Ralpha station, be both commercially owned and commercially operated.

What is the market? Activities likely to be supported in orbit by both governmental agencies and commercial/ industrial projects are:

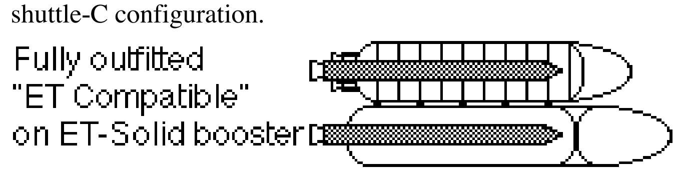
√ Astronomy
√ Life Sciences
√ Experimental agriculture (centrifuge hosted-hydroponics)
√ Zero-G or micro-gravity research and processing.
√ Manufacturing feasibility research and manufacturing

Those (in addition to the station's regular crew with their own habitat module(s)) coming either to work or to tour and visit will need the following:

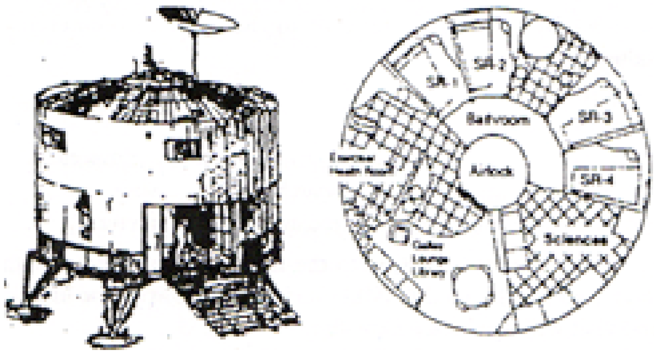
√ zero-G-proof facilities with locomotion and position-keeping aids and adaptation assists
√ exercise facilities
√ work stations
√ other research and study facilities
√ an observation cupola or viewport, inspection port
√ additional communications facilities
  * press interviews
  * conference calls
  * family calls
  * program origination broadcasting facilities
√ assembly lounge facility (= dining, entertainment center)
  (Nb. meals could be taken with regular station crew)
√ games, entertainment center, audiovisual library
√ half as many berths as design guest capacity, on a time-share shift-assigned basis. This provides for more efficient 24-hour use of work, recreation, and sleeping facilities alike — no underutilized space. Six berths seems a reasonable initial size to support the early market. An upgrade would be a dozen berth cores with movable partitions between them to provide elbow room when occupied.
√ toilets, showers - hygiene facilities in general.
√ one "permanent" staff member with medical and other training appropriate to serve as host and decision maker.

Two "prefab" hotel design architectures seem plausible:

√ A very spacious in-orbit modified Shuttle External Tank with a docking port in an Aft-Cargo-Compartment (ACC) for real "growth potential". An option would be to boost to orbit a ready to use ET-based facility, sent up dry attached to a fueled ET and double booster pack, in the proposed shuttle-C configuration.



√ A functional mockup of the proposed Mars Habitat Module in Bob Zubrin's "Mars Direct" mission proposal: [see MMM # 42, p. 3, FEB '91] a cylindrical pod 27.5 ft in diameter (same as the ET), two floors (16 ft.) high with nearly 600 square feet per floor. It could be attached to the station by NASA to test its flight worthiness and debug its systems in an extreme environment closer to home. This choice, more in scale with the proposed station, kills two birds with one stone, providing a small but functional commercially-run orbital hotel and preparing for Mars exploration (perhaps earning it a hefty NASA subsidy.)



ABOVE: Artist sketch of Zubrin's Mars Habitat Module and the floor plan of its habitation deck. For station hotel use, the "cargo floor" could contain science and/or utility systems equipment or additional private berths and common space.

While usually "tourists" need only minimal special "preparation" for their tour or expedition, it seems prudent that all visitors to the station hotel in this early phase undergo some qualification process with some subsequent training. There will be physical qualifications and others requirements.

The amount of training tourists or would-be hotel guests will need will depend on relevant past experience, from as little as 2 weeks to as much as 6 months. A certification process (and certification maintenance program) are likely.

While the early market may be dominated and pump-primed by official visitors and commercial/industrial visitors, there will occasionally be upcoming vacancies that can be filled by lottery winners, affluent globe-trotters, press persons on assignment, etc. Beginnings are always humble. **GDF**

"Swirl" features on Moon may be significant

from Andy Reynolds, Rochelle, Illinois

The October '94 issue of Astronomy has a story, "A Swirl of Moondust" by Bridget Mitz Tesa, about a lunar surface feature known as "swirls" or "swirl fields". These are just what the name implies: patches of what appear to be swirls on the lunar surface. They found out during Apollo that they're related somehow to high local magnetic levels on the Moon.

A couple of the possible explanations for how they were formed have some interesting implications for lunar settlement. One is that they were caused by the late maria basin forming bombardment. Most of the swirls (and magnetic concentration) are nearly directly opposite the big basins, and investigators think that the seismic waves from the impacts might have propagated through the Moon and hit the other side, bringing deep magnetic material (like concentrated iron) near to the lunar surface. Another possible formation theory is that they were formed by cometary deposit in more recent times. In this case, then the swirls could be surface deposits of iron and other magnetic dusts from the nucleus of the comet. Either way, it would be kind of interesting to go there and look for resources, No?

Rural Luna

pk

Part I: Beating a Path

For the utmost part, the Moon remains a pristine, undisturbed, trackless barrenscape presenting varying degrees of difficulty and obstacle to those who would traverse it. There are the wheel ruts of three Apollo Lunar Rovers and two Soviet Lunakhods — but that's it. This presents would-be developers and settlers with two complementary options: bring or build "off-road" vehicles and be content with the speed and terrain limits they impose, and/or improve logical easy-traverse routes into roadways passable for general vehicles at more desirable speeds.

The former option must be addressed with more capable, more specialized vehicles, and is covered last. The later, choosing traffic routes and improving roadways is our opening topic. MMM

LunaRoads

pk

by Peter Kokh

The question of roadways needs to be addressed on both a local and global level. The traffic in local areas within a base or settlement perimeter will be the heaviest and most regular, calling for the highest level of improvement. This means not only grading and removing of stones and boulders, but also compacting and "fixing" or "paving" the surface. Such traffic ways need not only to be rut-resistant, but also to be dust-free or dust-stabilized.

Some have called for paving with locally produced concrete slabs of "lunacrete." But road surfaces can be self-paved by fusing or sintering the surface layers to a sufficient depth to support expected wheel weights, using microwave beams in a stereo array or focused solar beams in a controlled pattern to produce a hard *but not glassy* surface, textured to improve traction of soft-tired vehicles. *Just how to do this* is a matter that will require some amount of determined experimentation, first Earthside with analog materials, then in-field/on-site confirmation tests with actual lunar produced materials under real conditions. This will be priority "homework" for the initial outpost-base.

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

As to "lunacrete", bear in mind that this is a sixth-weight environment and the "pavement" need not be as strong as that needed to bear up under terrestrial traffic. On Earth, a six to one mix of raw on site soil with cement is enough to produce a serviceable walkway (we continue to use a 1:1 mix in overkill due to the resistance of vested interests). But such a mix might even sustain road traffic in the reduced gravity.

"Highways" beyond the Base/Settlement Perimeter

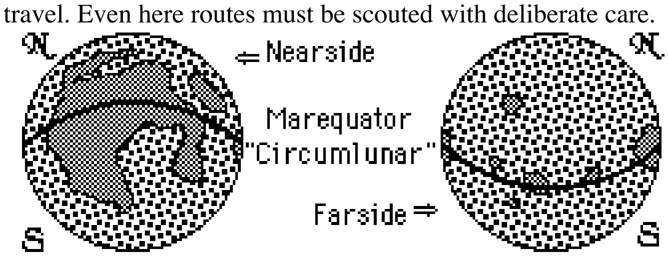
Away from the settled areas, dust control, while always helpful (reducing and simplifying vehicle maintenance) will be less important. Depending upon traffic volume, simple clearing of boulders and modest grading here and there may suffice over carefully surveyed routes. Rights of Way can be very generous, all at no cost. Obviously surveying will be of the utmost importance if the amount of work and expense required is to be kept to the most economical minimum. That will be a primary goal in the early era of human occupation. Only as global lunar population growth and intersettlement traffic justifies will "shortcuts" demanding extensive cut and fill work, perhaps even bridges and tunnels, be justifiable.

To aid in route surveying and "highroute" corridor designation, we will need more accurate and higher resolution lunar global altimetry maps than we now possess. But this is quite within the reach of (a) satellite mission(s). Based on the maps yielded by such (a) TopoSat(s), potential corridors and routes of varying breadth, both main and tributary branch routes, can be identified prior to decisions on where to site additional settlements and outposts. Proximity to such routes linking potential sites to the initial and main center(s) of lunar population will be a primary, if not overriding consideration in final site selections. This map of potential traffic routes, color-coded for sections needing special improvement, identifying and quantifying clear-grade (CG) and cut-fill (CF) hurdles according to difficulty and expensed options will provide one part of a crystal globe preview of the way the Moon, as a new human world, will unfold and develop.

There are of course, other ways of getting around both on, over, and above the surface and to the extent to which these prove to be economically competitive, they will tell a complementary story. Here, actual site advantages, be they chemical-mineral endowments or scenic spots of tourist appeal will mandate the development of sites irrespective of any convenient proximity to this Map of Potential Highroutes But this map too, will be penciled in well in advance, again thanks to orbital satellite mappers, this time tracing the abundances of elements and even minerals. It will form the complementary part of the lunar development blueprint map.

The "Circumlunar", Route L1

Open a photographic lunar atlas or get out a lunar globe, and it will be clear at once that some areas, notably the mare plains, are suggestively more travelworthy than the highland jumble of crater upon crater. This is deceptive, however. Lava flow fronts, escarpments, and rille valleys and trenches as well as "reefs" of partially buried crater rims pose very real restrictions on choice of path in cross mare and inter mare travel. Even here routes must be scouted with deliberate care.



The second thing that should emerge is that the distribution of the maria is far from random. They cluster north of the equator on Nearside, and south of the equator on Farside. It is indeed somewhat justifiable, even practical, to speak of a "marequator", a lunar great circle that traverses the geographical equator at the visible limbs and tangents 30° N at the central Nearside meridian, and 30° S at the central Farside meridian. A future "Circumlunar" Highway might well follow this route, with branches of opportunity off to either side.

Scenic Highroutes

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

Finding one's way, safely

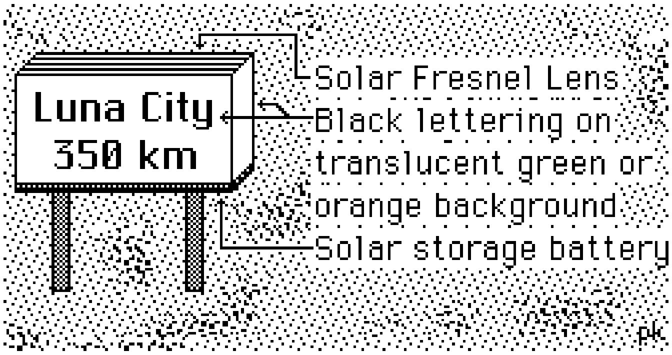
In addition to the constraints on choice of materials and construction methods posed by the extreme range between nightspan and dayspan temperatures, there is the challenge of the accompanying differences in illumination. In dayspan, the glare from reflected sunlight is intense. This is so despite the dark grays of the lunar regolith soils even in the highlands. Add to this the inky black shadows in an environment free of a light diffusing atmosphere. At night there will be some relief on Nearside from earthshine, phase for phase as bright as sixty moons on our own cloudless nights. But in Farside, the pitch dark of nightspan will be relieved only by the brilliance of the Milky Way in the Earthless sky.

The problem these extremes of illumination pose is twofold: first there is the need to see one's way clearly. Second there is the defensive need of being visible to other vehicles.

Helping in the first instance is the lack of atmosphere and drag: we can put headlights on high masts so they can peer over slight rises. By day, to save battery or fuel cell power, they can be computer-toggled by the coming into view of dark shadow areas along the line of motion on the road. At night, sidelights as well as headlights may be desired. Question: how practical would it be, on Earthless Farside, to drive solely by the light of ultraviolet headlamps? That is to ask, is there enough fluorescent rock, glass, and dust to be excited by the UV? Some cheap experiments with a representative sample of Apollo Moon rocks and dust could give a first read.

To be visible to others poses special problems both by day and by night. It will be very important to determine exactly which colors and hues and shades stand out most clearly against the lunar grayscapes. Will reflective bright green be the color of choice on the Moon as on Earth? Possibly not. Vehicle nightlighting can likely follow familiar terrestrial code norms: red, orange, green, white, blue.

Allied to the above question is the choice of colors and auxiliary illumination for road markers and signs. During dayspan illumination, signs could be designed to make use of sunlight for enhanced visibility. Under shadow and nightspan conditions, battery-stored solar energy could use the same design for internal illumination. To save energy, these could be switched on, and off, by vehicle proximity sensors.



Alternately, night lighting of signs could be supplied by radioactive isotopes and a careful choice of fluorescent materials or. In both cases, translucent colored glass would be used, not plastic.

Not by sight alone ...

To paraphrase a proverb, visibility is not enough. On Earth, both to attract attention of distracted drivers and to provide warning, for example on blind curves, horns are all but indispensable. Conventional horns do not work in vacuum. Radio-triggered horns would seem an option, but without obstacle-top relays, their line of "sight" would be broken. We will need to address this problem, either as suggested above or otherwise.

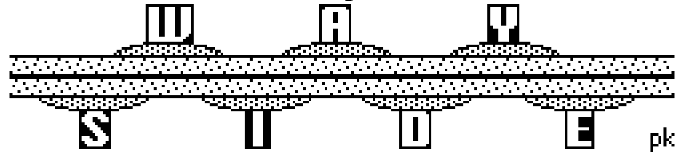
Radio communications will have to be satellite- or tower mediated. There is no ionosphere! We could rely on relays at L1, and much more distant L4 and L5 and Earth itself, the latter three all with their 2.5 second time delay. Or there could be a more expensive to maintain low orbit network satellite array. Low lunar orbits are unstable and lots of maintenance fuel would be needed. A tower net might be the simplest solution until the human presence starts to spread globally. At any rate, a satellite net for global positioning information will be indispensable on the Moon where visible location clues will be few and confusing.

For entertainment and news on route, lunar radio stations could reach travelers by the above satellite relays. Antennas large enough to pick up signals from L4 or L5 could also bring in Earthside stations. Conversely, terrestrial dishes big enough to pick up signals from L4 or 5, more than ten times the distance of geostationary comsats now in use, would be needed to eavesdrop on lunar programing, either direct or reboosted by relays in L4 and L5.

On farside, especially within relay line of sight of a radio telescope installation, communications may have to be carried by roadside cable with intermittent low power short reach radio transmitters. More conservatively, milestone road-side lights could flash to advise vehicles to park and do a cable hookup to receive an important message. As a site for such an astronomy facility, probably indispensable to any successful S.E.T.I. search as well as to definitive cosmology, lunar Deep Farside is a piece of real estate unique in all the solar system, of such scientific value that its radio silence must be protected at all costs, despite all inconveniences. Our ingenuity and need will find a way to communicate there all the same. MMM

Relavant Back Readings from MMM :[MMM Classics #2]
#10 Nov '87 "Farside" part II; #15 MAY '88 "Rural Luna"

The Basic Automated Unpressurized Convenience



by Peter Kokh

For traveling off the beaten path, obviously we must use self-contained vehicles that need no resupply other than that which they can obtain from the surroundings they traverse. A tall order, especially if range is not to be severely limited.

But along improved high routes opened to routine travel, wherever the distances between settlements and outposts are substantial, safe travel will be promoted by the placement of basic automated unpressurized convenience waysides. These will be stations where vehicles can pull up and hook up for refueling or recharging, access higher gain antennas for fuller communications options, and so on. take on emergency rations when needed, etc. The station's solar power units will recharge exhausted batteries, electrolyze water from fuel cell operation to make hydrogen and oxygen for refueling other fuel cells. And there will be on site solar power storage for limited nightspan operations. First aid supplies will complement emergency food rations in a vending dispenser.

A computer in the main settlement could keep track of vended inventories and the quantities of water, hydrogen, oxygen, stored power reserves etc. On that information, just-in-time resupply and equipment maintenance can be scheduled.

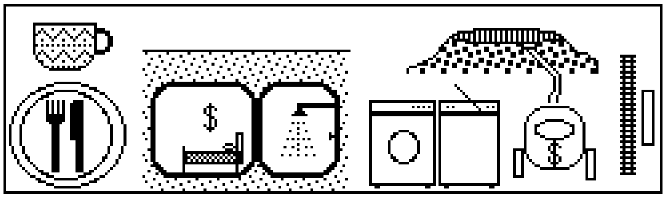
Such automated stations can be designed as compact units with modular pull-out/plug-in changeable components. They could be trucked to the site overland, or delivered ahead of road-blazing crews to areas about to be opened by suborbital hopper or lunar all-terrain vehicles.

While vended food rations and other items would need to be resupplied regularly, the fuel and power services function could largely be self-maintained on an automated basis along with recycling wastes from one vehicle into reserves for the next. Use of the station other than through vending machines could be on the honor system.

As a major improvement, an emergency solar flare shield in the form of a regolith-covered canopy or ramada could be provided at waysides separated by no more than a couple of hours drive. And a self-service garage with a ramp, hoist, and vending machines dispensing commonly needed replacement parts would be another useful improvement.

Even before truly rural pockets of habitation appear on the Moon, the presence of these little automated stations will put the welcoming and reassuring stamp of "civilization" on the long desolate inter-settlement and inter-outpost reaches. These stations could be manufactured for, and operated by the Lunar Frontier Government. But they could just as well be built and operated commercially under license with set mini-mum standards. The latter option, probably leading to rival competitive chains, would promote welcome improvements, such as the two we've mentioned above, as well as more efficient operation and maintenance. Commercial operation will also more quickly lead to the appearance of staffed full service stations and centers. MMM

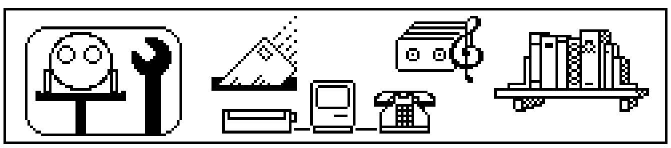
Service Centers & Inns



by Peter Kokh

Some of these basic and improved Automated Stations may continue to serve indefinitely in this limited capacity. But where traffic growth, and hence entrepreneurial opportunity warrants, well-placed stations (at junctions and crossroads, near scenic attractions, for example) may gradually evolve into full time staffed service centers. The artwork above depicts just some of the service opportunities: coffee shop and restaurant, motel with shower facilities, laundromat, excursion tours to scenic spots, lunar railroad flag stop.

This list is hardly exhaustive. As this would be a pressurized station, matchlocks would be provided for vehicle docking, permitting shirtsleeves entry. For the vehicle, in addition to the standard utility/service hookups, there could be a garage with mechanic on duty and a more complete inventory of parts. There could also be a sanitary waste deposit facility. A first aid station would be tended by a nurse or medic.



There could be a more complete line of telecommunications: postal pickup for snail mail; western union style pick up anywhere service for messages and money; ATM machine; telegraph/fax service; computer/modem work stations; teleconferencing capacity. For the motel section there could be a well-rounded audiovisual library

We mentioned available excursion tour side trips. Expanding on this theme, other possibilities include rentals of open cab lunar dune buggies and dirt bikes; taxi service; and, of course, day care for the little ones you don't want to take along on that special outing.

A lounge for guests to mix socially could complete any dining facilities. It could be stocked with an assortment of games. Besides a kitchen and meal service, there could be an in-room kitchenette, even picnic supplies for an outing in an attached solarium-arboretum-garden under a glass dome (total accumulative time spent under unshielded glass is likely to be minimal). A small gym, a ball court, or pool would be nice.

Expanded tended vending service could include various food and sundry items, locally made or other lunan art and craft souvenir and gift items, on the spot film developing and more. Each Service Center & Inn might offer and carry certain basics. They would try to outdo one another in luxury options and specialties.

In reality, the first such centers are likely to develop as truck and motor coach stops. It may be a while before lunar roads are traveled by any lunan version of the family car. But any of the above would be a start. MMM

[Lunar Roads, Part II:]

Vehicle Design Constraints

pk

by Peter Kokh

It might seem that designers and engineers of vehicles meant to roam the lunar surface have a clean slate. First, there is no atmospheric drag to contend with, therefore a need neither for streamlining nor for a low, narrow cross-section profile. Second, there are no real estate expense reasons to keep road rights of way and traffic lanes as narrow as those we are well accustomed to on Earth. Lanes, and the vehicles that ply them, could be radically wider. — So it would seem.

In reality, some relevant considerations are important enough that real constraints on vehicle design emerge.

Dust Control ➔ *"Dustlining"*

The Apollo Astronauts found the powdery lunar dust to be quite troublesome. In short, they had a "static cling" problem. We should be concerned with two things; first, dust working its way into moving vehicle parts, compromising their smooth operation and operating life. Second, we need to minimize the migration of dust into habitat areas.

While electrostatic control may indeed be part of the solution, we'd do best to approach the problem from redundant overlapping angles. In the latter case, we need to minimize or altogether prevent foot traffic from the outvac into the habitat areas. Where some in and out space-suited traffic cannot be avoided, paved or "fixed" porches and approaches will help for pedestrian and vehicular traffic alike.

As for the vehicles themselves, the underside can have a dust-shield pan, that minimizes the number of catch basins for vacuum born dust. On Earth, streamlining has affected most the frontal and upper surfaces of a vehicle. On the Moon, a somewhat analogous dustlining will affect the frontal and lower surfaces. We must learn a new, yet familiar, set of tricks.

Saving atmospheric gases ➔ *"Snuglocks"*

There is a seemingly limitless supply of Oxygen on the Moon. But the point is that the high lunar vacuum is an invaluable scientific and technological resource. It pays to do everything possible to minimize any slow degradation this vacuum will undergo from repeated airlock cycling.

More importantly, however, at least in its immediate economic ramifications, is the principally exotic, or Earth-sourced nature of the Nitrogen we will need as an atmospheric buffer gas, one with biospheric importance as well. In short we need to conserve both oxygen and nitrogen. One way to do this is to use matchlocks instead of airlocks for the delivery of goods and personnel between the exterior vacuum and the pressurized interior. Direct docking allows shirtsleeve passage.

Those who must enter and leave, either the vehicle or habitat, on foot, can use turtleback suits, backing into a form fitting lock. Once secured with a pressure seal, first the concave mini-door to the habitat opens, then, into it, the conformal back of the turtle back space suit. The occupant reaches backwards inside the habitat for a bar above the turtle lock and pulls him/herself through the turtle back into the pressurized habitat. The dusty suit remains outvac. The back of the empty suit, then the door lock is closed, and the empty suit moved by a roboarm to an exterior storage rack

More salient here is the periodic need to bring vehicles into pressurized garages through large airlocks. The only way to minimize volatile loss in this case is to design vehicles so that all top and side-mounted protruding equipment retract into hollows in the hull, even the wheels can tighten up for the taxi in, so that the vehicle fits through a much smaller standard size garage airlock as snugly as possible. This snuglock would have a conformal antechamber exposed to vacuum, so that when the airlock was opened, vehicle in antechamber, the outrush of air would be minimal. In other words, the type of vehicle we need as a mainstay is a "Snugger."

Ease of Maintenance ➔ *"Modular Drive"*

There will be times when repairs must be performed outvac, far from a friendly snuglock. Much difficulty can be avoided if all repairable equipment was part of a modular pop-out/snap-in subassembly. For example, an electric power unit in a removable tray could feed power to four independent motor-wheel drive units that could in turn be switched with one of a pair of spares in a few minutes, the particular item needing repair to be taken care of later in a pressurized garage.

Similarly, air/water/waste recycling systems should be in easy to exchange pop-out/snap-in trays.

Road worthiness ➔ *"wide, low, shielded"*

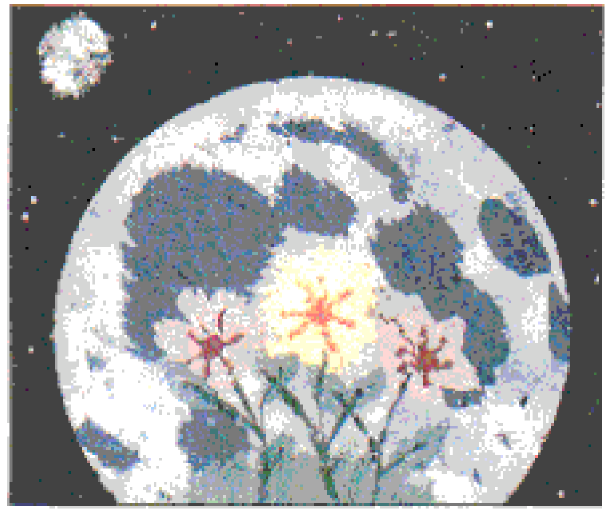
The salient features of the lunar motoring environment in addition to its dustiness are the low 1/6th Earth-norm gravity or sixthweight, and vulnerability to occasional deadly solar flare storms. To tackle the first, the wheel units, vehicle outside the snuglock, should extend well to the side, reptile style, rather than below, mammal style. Road lanes can be as obligingly large and accommodating as pragmatism demands.

In addition, given the equally reduced traction, the center of gravity must be kept as low as possible, even though ground clearance may need to be generous, especially for off-road vehicles. In this latter case, a vehicle can ride low when the path is relatively level and boulder-free, then automatically rise up to clear obstacles picked up by its proximity sensors. For vehicles that spend their lifetimes on improved roadways, the problem is minimal. The wide track, a cabin slung between the wheels, and common sense positioning of heavy equipment and fuel tanks will keep the center of gravity low enough.

For unpredicted surprise solar flare emergencies, there could be a movable rack of empty tanks, normally kept topside, but deployable over the aft end when the Sun was lower to the horizon. Fuels like hydrogen and oxygen and fuel cell waste water could be pumped to these tanks as needed, the vehicle parked, its butt to the Sun, covered. Having more heavy equipment over the rear axle, compensated by cantilevering the control cab over the front axle, should help.

NEXT MONTH: Vehicles for Opening Rural Luna

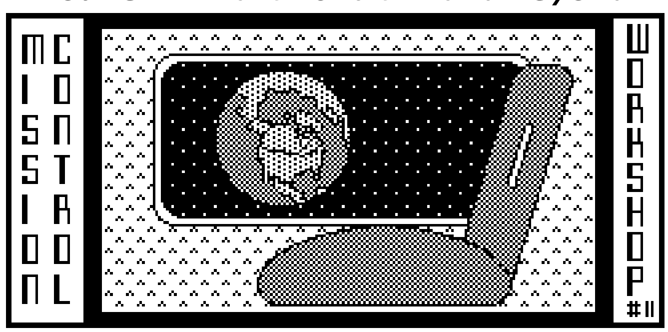
MMM #80 - NOV 1994



Lunar settlers *will* be able to "paint" using only materials derived from the regolith soil around them!

Above is "Moon Garden #1", reverse painted on an 8"x10" piece of glass, by MMM Editor Peter Kokh. The "paints" are *not* solvent based and incorporate no organic substances even as additives. Instead an inorganic adhesive (the only one known), sodium silicate is used to suspend either raw regolith powder or colored metal oxide powders. The palette is still limited and the art form undeveloped. More candidate lunar-sourceable colored powders are sought, as well as other artists, with more real talent to push the new medium to the fullest. More below.

"Tourism in Earth Orbit — and Beyond"



May 28th, '94, ISDC '94, Toronto, Ontario

Led by Peter Kokh, Mark Kaehny, George French

Part 3: An Expandable Luxury Earth Orbit Hotel-Resort: Beyond Motel 6

Peter Kokh, discussion leader

TEAM: James McEnanly, Goana Milosevic, Murray Wilson, Janet Jones Smith, Hugh Dietrich, Dennis Pearer, Bill Bogen

MISSION: Assumption: Market demand i.e. ticket prices now make it possible to build a luxury hotel in orbit. It will have artificial gravity sections at Earth-normal, Moon-normal (1/6 G), and Mars-normal (3/8 G). There should be 50-150 guest rooms with at least double occupancy. They will be compact but comfortable (more akin to Amtrak than cruise ship models). The hotel should, however, have generous exercise room in a non-rotating zero-G hub. Take time to consider what other amenities are worth the cost to guarantee a "thrill of a lifetime stay" and how little/much room they merit. There should be generous Earth-viewing and watching lounge areas. How about a "screened in" "outvac" sports area to frolic in with untethered space suits?

Design a facility that is both easy to construct and finance. Assume that only Earth-sourced components are available at this time. You should probably work with prefabricated modular elements like ET-Compatibles, outfitted on Earth and boosted dry (in place of an Orbiter) or more compact modules, rather than design some stunning megastructure that will require extensive on orbit labor to assemble. There should be two or more docking ports at a minimum. You will want to keep total per capita (guest & staff) weight (and number of launch loads) to a minimum.

It is important that the design not be fixed in size but able to support continuing hotel expansion as tourist demand warrants. The special constraints imposed by artificial gravity are to be considered here. If you have time, show phase by phase expansion and what might be added: rooms, suites, conference areas, shops, other tourist- and business-oriented activity areas.

Your purpose in all this is to expand on your own thoughts and help illustrate to others some of the logical possibilities.

WORKSHOP RESULTS:

The way this group worked, various ideas and trial balloons would be put forth by each of us as they came to mind no matter which heading they came under: guest facilities, guest activities, recreation, food, services, structure, future expansion — if this free-form process seems unruly, it is exactly what is needed. For, after all, everything bears on everything else and to tackle each heading in sequential isolation is to guarantee our missing important definition and design opportunities. The moderator's job is to help others flesh out their ideas, suggest repercussions and enhancements, and get the discussion back to unfinished business. A synthesis of our brainstorming follows.

What Hotel Guests Will Want

The View: Individual Quarters, or at least Premium Class ones, should have shutterable portholes from which to gaze on the planet below: landforms, mountain ranges, rivers, coastlines, seas, clouds; and, on the nightside pass, the ballet of lightning flashes and metropolitan city lights. Common areas such as a combo Dining/Lounge/Library/Assembly hall should also provide generous Earth views.

Floating Free: For those able to adapt to it without space sickness (about half of the general population), the ambient zero-G will be something to enjoy. There should be some assists, however: velcro shoe soles with convenient attach points here and there, handrails, visual cues, possibly color coded to help maintain orientation. There needs to be a zero-G gym with exercise equipment and a room for supervised structured activity: aerobatics and dance.

One permanent staff position may be **zero-G choreographer/dance instructor:** someone who is as at home in weightlessness as cosmonaut Andrei Krikalev. [Those who have seen videos of this cosmonaut at work in Mir will have been awed by the sheer Manta-like grace with which he effortlessly swims/flies around the facility with no wasted motion). Guests so inclined could schedule practice sessions several times a day and by the end of their several day-long stay may be good enough at individual, paired, or group free-fall dance to stage a show for the rest of the guests, and have it videotaped, if not televised live, to impress friends at home and preserve a unique memory. as well as to further entice those thinking about buying a similar out-of-this-world vacation.

The zero-G dance hall might be a spherical inflatable, with a post-inflation inner armor of metal applied through the vapor deposition process. Creative placement of mirror segments would enhance the experience and provide feedback to neophytes. For "gala night" show and tell, disco and strobe lighting could further theatricalize the performance.

Restaurant: granted that some will have little appetite in weightlessness, one intriguing suggestion is that culinary experimentation may yield gustatory delights that could not be created in a gravid location (on Earth, on the Moon, on Mars). This may or may not be the case and calls for "orbit-truth" demonstrations after considerable brainstorming. If the idea proves out, free fall foods and drinks may someday provide an added incentive to take an orbital vacation.

Artificial Gravity: Why reproduce *Earth-normal* gravity? Are not our guests out here to experience something *new*? **One-sixth G** or sixthweight, the fractional gravity level of the lunar surface would be easier and less costly to reproduce: it would require only 1/6th the radius and correspondingly reduced structural mass at any given rotation per minute level. Yet this level of gravity is more than sufficient to support normal physiological processes, provide firm orientation, and guarantee freedom from space sickness. Most LEO hotel guests might welcome this chance to experience what it would be like to walk on the Moon. But more about this later.

The Lunar Section should have a dance-floor (glass see-through: stars, Earth??), also staffed by a sixthweight-adept choreographer/dance instructor. Again, by the end of stay, some may want their gala night public performance videotaped.

The Lunar Section should also have some sort of ball court in which, thanks to a succession of experiments by a succession of guests, new sport forms fun to play and watch in the Moon's lower gravity could be developed and debugged. We could start by trying racket ball and **Jai Alai**, and making trial adaptations. Eventually, the results might be good enough to make ABC's Wide World of Sports and other TV Sports Magazines. A **swimming pool** in this section would attract **divers** who could go through fairy-tale like routines before finally hitting the water. Again likely fare for Earthbound viewers greeen with envy, and great promotional material for the hotel. If possible and practical, a perimeter **jogging track** of some sort would be welcomed by many.

Because artificial gravity introduces a coriolis effect on motions within its “field”, both dance and sports in an orbiting hotel Lunar Section would give rise to a characteristic “english” that would not carry over to the Moon settlement itself. This “english” will be hard to learn because it will matter greatly if one is facing spinward (“east”), antispinward (“west”), to the right of spinward (“north”) or to the left (“south”). Standardized **orientation color cues** on the walls, something that the subconscious mind can learn to take into account automa-tically, should help greatly. Of course, some will pick up on these cues faster than others.

Both zero-G and reduced gravity sections may some-day support **sanitaria**, places where enhanced recuperation may be possible. This assumes, of course, that patients are not only well-heeled, but able to stand the stress of getting here in the first place.

A small museum or historical area would be logical. Guests would be amazed with displays of primitive free-fall toilets and dull meal-fare, and more gratefully appreciate what civilized improvements progress has since made possible. Of course, such facilities could also or alternately be provided at Earthside aerospaceport gateways..

Orbit may become as popular a honeymoon visit as Niagara Falls. Honeymoon aside, the idea of simply being married in space should draw more than a few. Zero-G or sixth-weight processionals could provide quite a memorable show.

Other Facilities: The hotel should have a well-stocked audio-visual **library**, an **observatory** from which guests could peer at stars and planets in their natural atmo-sphere-free twinkle-not brilliance. A **communications center** should provide phone, visiphone, fax, electronic mail and internet access. A tax-free **casino** with zero-G games could be a novelty for those not up to more aggressive pastimes.

The hotel should not only support teleconferencing but have some meeting room and conference space and a newsroom available for on site anchoring of major network newscasts. More imaginatively, a properly decorated alcove with table and chairs and Earthview picture window backdrop could conceivably become a favorite site for ceremonial signing of important international treaties.

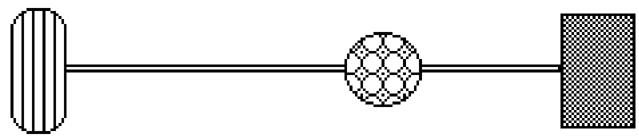
Stores, Pantries, Supplies: There should be emer-gency caches of non-perishable food preserves, water, oxygen, power, medical supplies etc. should the normal scheduling of freight resupply flights and passenger craft be interrupted for any reason. There ought to be a full time nurse and paramedic able to perform most of the more common surgical emergency routines under radio/TV guidance from the surface.

Earthside Gateways to Orbit

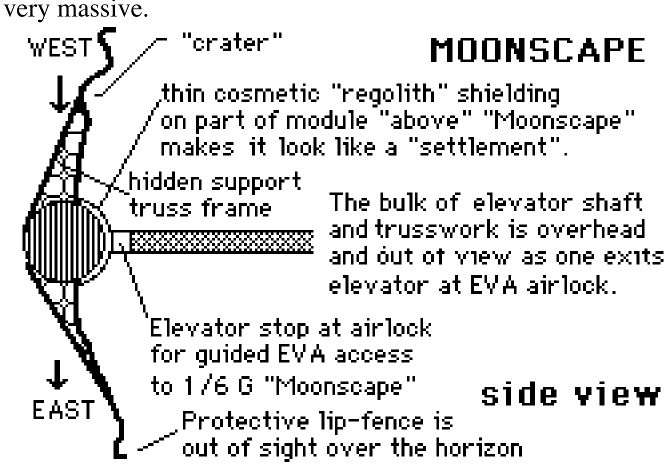
Given that the Orbitel should cater to international trade, and given the need to get 24-hour service out of all common facilities and equipment, an elegant solution would to have three near-equatorial gateways for shuttlecraft (NASP or Delta Clipper) feeding the hotel. One for the Americas (Bogota and/or Quito international airports?), one for Europe-Africa (Nairobi?), and one for East Asia/Pacific (Singapore?) This would feed a natural three shift rhythm without inflicting a jet lag handicap on anyone. The national carriers feeding those aerospaceports would logically prosper in the traffic and prestige.

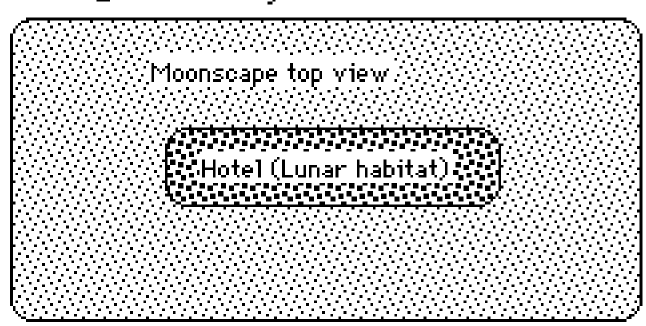
Architecture and Expansion

This is fairly well determined by the decision to include both weightless and simulated lunar gravity sections in the hotel. A dumbbell arrangement would counterbalance a service, maintenance and supplies section at one end with the 1/6th G guest quarters at the other with a non-rotating hub in the middle. As with a teeter totter, the two ends need to be neither of equal mass nor equidistant from the hub. The heavier end need only be proportionately closer to the hub , as it were a fulcrum.



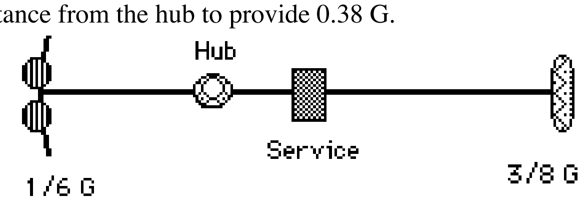
One expansion we considered was to create a simu-lated Moonscape, in which the Lunar Wing of the Hotel was “buried”, to give suited guests EVA access to the 1/6th G “surface”. Such a feature need only be “skin-thick” i.e. not very massive.





The “Lunar Experience” could be heigtened by using only furniture and furnishings that might be duplicated on the Moon using materials that could be processed locally in the early settlement. There could even be an optional Lunar “menu”.

If at the same time the Lunar Wing of the Hotel is doubled or twinned, the total excess weight could be counter-weighted with a new small Mars wing a bit more than twice the distance from the hub to provide 0.38 G.

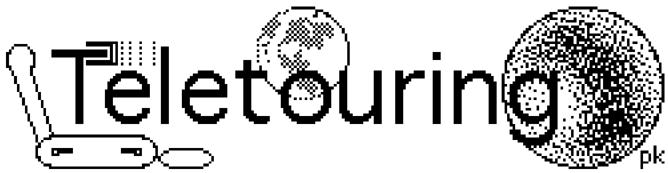


The Service Complex can be positioned anywhere along the axis, to either side of the hub as needed to balance the Lunar and Martian Wings.

The idea of an orbital amusement park was mentioned but not elaborated.

SUGGESTED READING:
MM Review # 12, JAN '93 pp 2-8
"The Frontier Builder: An Earth-Moon Hotel Cruise Ship"
by Doug Armstrong and Peter Kokh.

Tourism in Space Workshop **postscript**



A Near Term "Terrace" on the road to a space based economy

by Peter Kokh

Orbital tourism is perhaps a generation away, lunar flyby tours following shortly. But land excursions on the Moon, and on Mars especially, are well beyond our horizon. "Virtual Reality" armchair excursions of these and other worlds, fed by orbiter and rover compiled data banks, seem to be the consolation prize we must settle for. The proposed LunaCorp mission has such an ersatz experience, available at theme park terminals, as its principal "product". It will allow viewers to "visit" Apollo 11's Tranquility Base and then trek cross mare to the Apollo 17 site in the Taurus-Littrow valley 600 km to the north northeast.

But "Virtual Reality", as amazing as it is, in its current state of realization, fools no one. The sense of being in and moving through the landscape at will is amazing. But the landscapes themselves have a cartoon like feeling, a low resolution smoothing of colors and shapes. Such "tours" will leave much to be desired.

Another near-term option is "telepresence". This puts the operator/spectator in the drivers seat "real-time". You see what the rover etc. sees. While the resolution will be much better, there can be only one telecontroller, while an unlimited number of others can join in "for the ride" as if on a guided tour coach. Unlike the telecontroller experience which has to be "live", the guided tour experience can be canned and replayed for others at any time.

Surface teletours of the Moon could be arranged before the turn of the millennium. They could even "visit" outposts in the form of landed scale models, to get beyond the sterile barrenness of an unending succession of unrelieved raw landscapes of rock and sand. Such fare would all too quickly satisfy the appetite of the most eagerly anticipating participant - "when you've seen one crater (or mountain or rille, etc.), you've seen them all".

Mars, it would seem, is too far for any sort of telepresence. But let's back up. Flyby and orbital teletours of the Moon might come first. And what about Earth orbit?

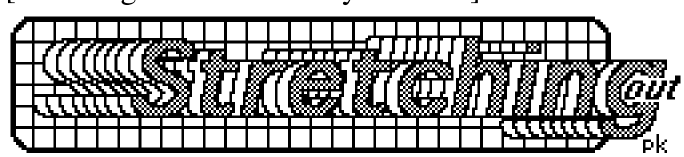
A satellite hooked to telepresence receivers could offer real time surround-vision experience of skimming over the Earth a couple of hundred miles up. Again, there could be only one telecontroller (steering or aiming the field of view) at a time - and again, an unlimited number of spectators could get a front row seat guided tour. And why not "guided" in the full sense of the word, with a voice describing notable features as they come into view, on the Moon or on Earth from orbit, as the case may be.

Such tours will require expensive equipment and so are a natural for theme park investment. There, the number of people using, and hence paying for the equipment will be large. In such a setting, it may even be possible to add to the illusion by simulating weightlessness. That is, telepresence could conceivably be enjoyed by a properly suited person in a neutral buoyancy tank.

But less expensive productions using telepresence equipment can be arranged right here on Earth. By this means anyone can tour remote areas and extreme environments on Earth: Antarctica, the Barrier Reefs, etc. Theme Park profits might be plugged back into more terminals, more rovers, etc. As word of the experience spreads, the whole scale of operation can be increased.

Looking for an entrepreneurial gold mine? One that will both make you money and help increase the pace of the new Lunar Reopening? Why not put together some capital and form Teletours, Inc. There's definitely a market out there, and you might get rich catering to it (rich enough, we hope, to invest in *real* space touring opportunities!).

[Avoiding "Sardine Can Syndrome"]



Usage, Layout, and Decorating tricks to creat Psychological Elbow Room in Limited Habitat Volumes

by Peter Kokh

This article is an expansive digest, if you will, of the spirited discussion involving panelists and audience at one of the LRS' Science Track panels at the recent First Contact I Science/Science Fiction Convention in Milwaukee. The title of the panel was "Beyond the Sardine Can: ways to provide habitat space with real elbow room".

We did eventually talk about bring-along inflatable structures and make-on-the-spot habitat expansion incorporating building materials made from local [Lunar, Martian, as the case may be] resources, that is, the possibilities on *in situ* construc-tion and locally appropriate architectures. But as a prelude, we discussed how we might make the most out of a bad thing. Constraining payload bay dimensions, faring sizes, and payload weight restrictions all work to make compactness *the* virtue of excellence. This is why, for all the extra sophistication and increased capability, space stations now on the drawing board do not offer much more volume than Skylab of a generation ago.

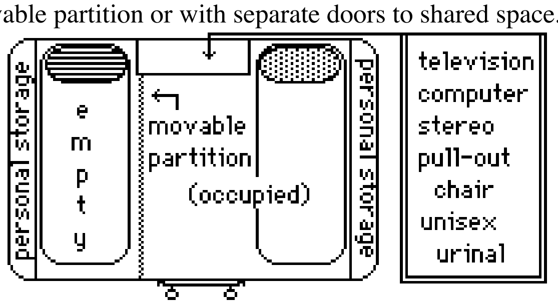
For indeed, we need *not* put up with what can only be called poor design, layout, decorating, and usage patterns that unnecessarily suffocate those living and working in early era confined spaces. NASA in recent years has given some uneasy and self-inhibiting attention to "human factors" in adding to its endless series of paper studies of space station and Moon Base habitat designs. The concessions allowed in by the engineers who continue to hold the whip over the architects may put off the onset of cabin fever by a day or two. They still have their priorities backwards.

Early commercial facilities will be affected by the same volume and weight constraints. But more attentive to employee/worker morale, they are likely to more motivated to draw from the wealth of human experience all about. Instead of grudging minor concessions, interior architects and designers of commercial facilities can borrow from a vast repertoire of tricks that humans on Earth living in cramped quarters have used to create substantial increases in psychological elbow room.

Usage Tricks

The first way to increase "spaciousness" is to cut in half, or even down to a third, the number of people likely to be in any area. We mean "time-sharing". We mean a staggered two or three shift day-night work-recreation-sleep pattern. We mean getting around the clock usage from all spaces, from all equip-ment, getting our expensive money's worth. Industry knows the trick well, some even cycling work week / weekend times.

Yes, NASA already has a 2-shift pattern in use aboard the Shuttle. But we can push this device further in a space or surface base. For example, if we can get beyond hot-racking in the sleeping quarters and provide individual berths, we can still time-share dead space elbow room between adjoining compart-ments occuppied on different shifts. We can do this either with a movable partition or with separate doors to shared space.



ABOVE: Time share dual compartment. The door has dual knobs and hinges. As occupying person leaves at end of 12 hr. sleep-relax shift, movable partition automatically shifts over and opposite door handle is enabled. Partition can be decorated to individual taste on both sides (colors, photos, paintings, etc.). Only the carpet color and works console is shared. Even here, each person calls up his/her own monitor screen design and his/her own hard disk. Here each person's quarters are more than doubled in free volume, while the space of the compartment pair is increased by only half. The partition could be folded back by mutual agreement.

Of course, the principles illustrated above could be realized in any number of alternative designs and with either less generous or more ample shared common space. The point is that for a small investment in actual space, each person's personal elbow room is increased greatly.

Layout Tricks

Have you ever seen a house, whose interior was very familiar to you, torn down, looked at the empty lot, and wondered how all that livability was supported in so small a footprint? Empty unstructured space seems small. Packed and structured space seems big. Counterintuitive, perhaps, but so.

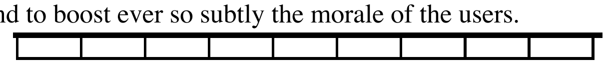
Similarly, compare a quarter square mile subdivision with a rectangular street grid with one with an interesting combination of curving streets, and cul de sac circles. Layout can make a big difference in the perception of volume. Being able to take everything in at a glance with long unbroken sight lines affords momentary amazement and guarantees perpetual boredom in quick succession. That is as true of Space Station Freedom Lab Module Mockups as it is of O'Neill space settle-ment "sunflower" cylinders or Bernal spheres.

What is wanted in either case is to create the sense of a mini-world. But "world" is *not* a place you can see all of in one sweeping pan. "world" is a continuum of broken horizons, some close, some far, only a small part of which is apparent at a time. In a "world" there is always "somewhere else" to go, places with different feelings and character. It's a terrible mistake to give that up, either deliberately or out of inattentiveness. We all instinctively know that, the way our homes are built is eloquent testimony to it, but the lesson may never have risen to the level of specific awareness.

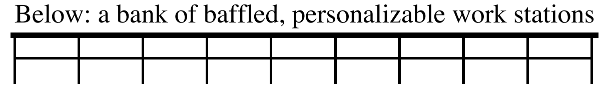
As it applies to habitat spaces, this lesson suggests two things: first modules should be combined in a variegated pattern. Angles of connection can be varied. The sequence of large and small modules can be varied. There should be both maze and easy interconnectedness.

Within a module, sight lines and trafficways should be broken. Open space should be more generous in commons and around work stations, less where the need to access wall panel storage, control boxes or service equipment is infrequent. In work areas, a lesson can be taken from modern offices created in large rooms. Each person's workspace is sequestered by 6 ft. high movable partitions, often fabric-covered for sound insula-tion and personalizable with assorted hangings and plants.

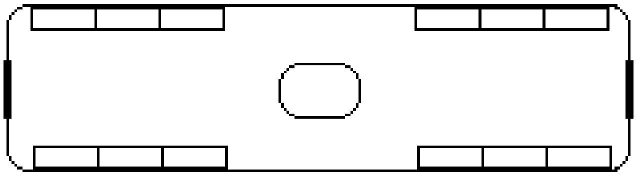
In more confining space habitat/lab situations, indivi-dual work stations can still be mutually "baffled". And since time-sharing will apply, there could be a general rule that the left-hand baffle surface belongs to one shift, for decorating purposes, the right hand surface to the other. This inexpensive feature, taking virtually no real otherwise usable space, will on the one hand work to control distraction and noise, on the other hand to boost ever so subtly the morale of the users.



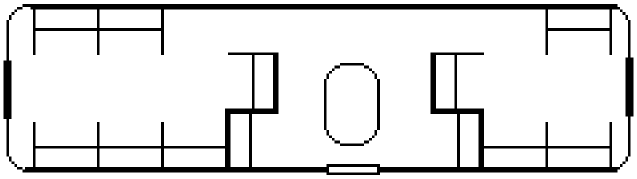
Above (plan): a bank of unbaffled work stations
Below: a bank of baffled, personalizable work stations



Breaking up long sight-line hall ways is important as well. The engineer must defer to the architect. Below: An unimaginative layout. Even an engineer will die here.



Below: an enormous improvement, yet same functions.



In the process of breaking up the layout, full attention must be given to acoustical control. Scattered zones of real relative quiet will increase the apparent internal spread of these mini-world volumes.

As important as the layout is the mix of spaces. People need places to get away from one another, and to meet in small groups as well as in an assembly of the whole. It is a mistake then to put all common space together. Granted each common space should have multiple uses to make sure that the space dedicated to it is used, and used as much as possible. All the same subdivision is possible. There should be "quiet" retreats (library/chapel) as well as lively spots (meals, lounge, games, meetings, films) equiped with a window to the outside.

Decorating Tricks: color and light.

Many things can work to subdivide, expand, and tie together spaces within spaces. Color is one. Color breaks that coincide with horizon breaks reinforce the individuality of the distinguished spaces. Ambient lighting should be used sparingly. Task lighting, by contrast, creates task-adequate individual pools of light, subdividing space without at all diminishing it.

If there is a bioregenerative life support system with food plants, this could be adjacent to the quiet area commons, especially if full-Sun overillumination is used instead of diodes. Nothing is so soul-renewing as a Sun-strength light flood.

Decorating Tricks: murals and mirrors.

Habitat and Lab Module "walls" are likely to be jam-packed full with functionality. Work stations, service panels, storage lockers etc. Be that as it may, there is always some dead surface, even if it be door and drawer fronts, that can serve double duty as opportunities to enrich an otherwise spartan decor. Color strips can run through door panels as well as dead wall. Mirror tiles are a possibility depending on location. Few things give such a subconscious sense of spaciousness, simply by relieving the eye, as a row of eye level mirrors.

In station mockups, two opposing surfaces are left blank to serve as visual ceilings and floors in the absence of gravitational ones. The faux "ceiling" could host a sky-mural, preferable on translucent panels over a running "light box". A wall in the ward area or other commons places could likewise hold a backlit translucent mural: a forest or meadow scene, a waterfall and river scene; a seacoast scene; a mountain scene; an autumn scene, etc. These could be changed with the month or with the season.

All of these things apply to early Lunar and Martian outposts as well as to space stations, indeed much more so because the crew stay times are likely to be much longer and the need to counter boredom, cabin fever, and depression that much greater. In both cases, habitat space will have to be shielded. Whether this is in a trench, a tunnel, or above the general surface terrain, the effect is the same. Either way, care must be taken to bring both the view and the Sun down into the living areas.

In the case of the view, the barren Moonscapes and Marscapes, however awesome, must also soon become intimidating and threatening in their life-hostile sterility. Arraying a shelf of plants, foliage and/or flowers, in front of a window will serve as a subtly reassuring filter through which to appreciate the view in a more healthy and balanced perspective.

Where tours of duty are long, not only should the base's pressurized space be "plexed", so should the time spent therein. Time can be "plexed" in simple ways. Seasonal or periodic changes of decor, especially in common places will help. So will holidays, feasts, festivals, and other events-to look-forward-to. But variation in the indoor climate-control can also help. Why not a "refreshingly crisp" morning here and there? Why not "evening breezes"? Why not occasional mist-cleaning of the air for a post-rain freshness? Why not vary the strength of the air circulation in non-work areas? Time can be structured both over long and short durations to provide more natural, more spontaneous variety.

Looking ahead

It will be some time after our return to the Moon before we can begin expending our *lebensraum*, our living space, with new modules built from materials made on site. This is so even if we do our homework and fully pioneer such materials beforehand using simulants and simulated situations. Meanwhile, with a little imagination, things can be made very much more livable with a little common sense.

Pioneering a Moon-appropriate art medium

WATERGLAZING

R&D Report: #2 — 10/13/'94

Peter Kokh, Initial Investigator

The high gloss varnish effect I had reported, applying pure waterglass (sodium silicate) to an unglazed brick, proved to be temporary. After about 2 weeks, the waterglass coat started to crystallize, slowly becoming flat and whitish. Yet the lunar simulant/waterglass suspension I had applied as a first proof-of-concept "paint" continued to be bonded securely to the brick. So waterglazes are flat after all! Yet, I suspected that if one were to paint on the reverse side of a glass pane, the painting would be effectively glossy when viewed through the glass. This would turn out to be the case.

Slow Palette Development

During the months since the first report, the chemist at Laabs, Inc., Tom Volkman, took an interest in my project and spent some time finding suitable powders, given the list of lunar element abundances I furnished. These included ferric iron oxide (rust), titanium dioxide (white), manganese dioxide (black), and sulfur (yellow). A second pass through his source books yielded chromium oxide (green). All of these worked well, by themselves or in mixed shades.

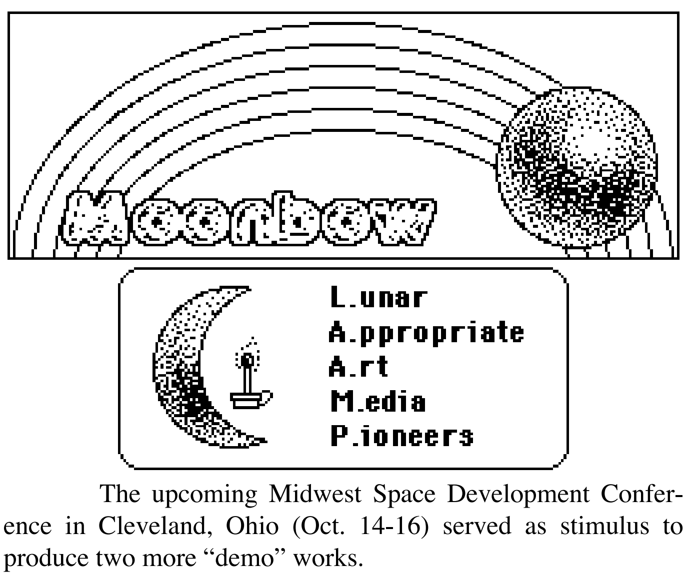
But three powders he found for me flunked the test badly, instantly coagulating upon contact with the waterglass, even producing noticeable warmth: chromium trioxide (magenta), nickel sulfate (turquoise), and potassium chromate (bright yellow). Perhaps other peroxides and salts will prove unsuitable as well. And that may severely limit the possible palette. To date I have no real red, nor a blue, the latter missed most of all. Other chemicals I might try (vanadium and cobalt compounds are likely sources of blue) are even more expensive.

The first ever Lunar Style "Painting"

Spurred on by an opportunity to display some concrete artwork, I conjured up a composition that would use all of the shades I had to work with, executing the piece Moon Garden #1 on the morning of September 30th, 1994 just in time for it to be displayed in the art show at First Contact, a new science/ science fiction convention in Milwaukee.

The painting was done on the reverse side of an 8x10 glass. Thus the foreground had to be painted first. The subject is a stylized full Moon against the backdrop of space, a full Earth in the right upper corner. In the foreground covering the lower half of the Moon is a cluster of flowers, leaves and grass.

Comments at First Contact were very favorable and there was general fascination with the concept. Encouraged, in the week that followed, I put together an initial 4 page newsletter about the project: ***Moonbow*** will come out as often as the feedback warrants. In it, I proposed a new artists' co-op to push the infant medium to its full capacity. It would be named L.A.A.M.P., Lunar-Appropriate Art Media Pioneers. L.A.A.M.P. dues (includes Moonbow subscription) are initially $10 a year and through 7/1/'95 a laser color print is included. **Make out to "LRS" and send to LRS P.O. Box.**



The upcoming Midwest Space Development Conference in Cleveland, Ohio (Oct. 14-16) served as stimulus to produce two more "demo" works.

"Greening the Gray" (taken from the refrain of a Lunar Frontier anthem I'd composed and published in Moon Miners' Review #7 AUG '90, it has a moonscape painted on the back side of an 8x10 glass, representing the past through the present, and a meadow and pine tree grove painted on the front side, representing the "surreality" of Lunar reclamation to come.

"Heinlein Roses" is a settlement "still life" painted on a 6x6 unglazed tile.

Waterglaze paints will work on metal as well, if the substrate is thick enough not to flex. And they could be used to decorate mirrors. The paints are mixed as needed, for waterglass suspensions dry and harden quickly. Small paper bathroom cups serve for mixing the suspensions, a turkey baster works to dole out waterglass in amounts needed. Still ahead are experiments with lunar-appropriate applicators: pads of steel wool?, of fiber-glass?, brushes of human hair?

Purposes of this Project

√ Develop a new art medium, one that lunar pioneers can use. At first actual settlers will use the raw "moontone" gray hues of unprocessed regolith, and perhaps glass microspherules sorted out from the moondust according to shade. In contrast the "processed" oxide palette will grow slowly. Meanwhile, lunar habitats and homesteads will start to look and feel "at home".

√ In the process, develop a new art form that is valid in its own right, whether the space frontier is settled or not. Thus earn income for terrestrial artists. Waterglass paintings will make great space center gift shop items.

√ Produce a public body of work which will concretely illustrate how lunar entrepreneurial self-reliance can work to make an alien environment into a human one, bringing the feasibility of lunar settlement to life in one small vivid way.

Hopefully, the word about waterglazing will spread and others will join in the fun. Once this effort is well under way, perhaps a similar parallel endeavor can be launched to play with lunar-appropriate ceramics, and art glass. If *you* are an artist or know someone who is, *please* help spread the news.

APPENDIX

The Scene at the Pavonis Metroplex

In your interesting bit of speculation on the suitability of Mars' Pavonis Mons to house a sizable urban complex, you mentioned that pressurized cross-connecting roads etc. might best be trenched into the surface. I'd like to carry your speculative illustration two steps further.

First, when the "highway" or whatever it is called crosses ravines, gullies, or other dips in the terrain, why not have it simply bridge these spots without shielding overburden.? The cumulative time spent in such sections of the tube would be minimal and result in negligible exposure.

Second, for less frequently traveled stretches, any such thoroughfares could simply run on the surface, through and within a continuous row greenhouse. If the atmosphere within was simply thickened Mars' Air (at the 0.1 bar you suggest), the passengers still could not "roll down" the windows, but the moral uplift of traveling through lush green 'fields' would be enormous,

Thomas Heidel,
Milwaukee, Wisconsin

[From MMM #71 - DEC '93]
Focusing and targeting our efforts...

"THE FRONTIER ENABLING TEST"

Space Frontier Foundation has developed a simple litmus test called "the Frontier Enabling Test" by which to judge the merits of projects and/or initiatives on which we may choose to take a position. This test can be applied to both government and commercial systems, technologies or policies.

A **"frontier enabling" technology** or policy is one which **accelerates or enables:**

1. **the creation of low cost access to the space frontier for private citizens and companies**
2. **our use of space resources**, and/or
3. **the rate at which wealth can be generated in space.**

In other words, *is* the project or policy going to provide a *return* on the national investment, "return" defined as *the economically sustainable human habitation of space*?

MMM Editorial Comment

This SFF test appears to be wholly in concert with MMM's own purpose emblazoned boldly in its masthead:

"Expanding the Human Economy through Off-Planet Resources."

We urge adoption of the Foundation's "Frontier Enabling Test" by the Lunar Reclamation Society and by any and all other pro-space organizations interested in more than cheering from the bleachers. Broad-spectrum space program advocacy *can* be wasteful of precious time, energy, and talent. We need to be as focused and targeted as we can be. The simple and succinct test above can serve us well as a handy tool to help direct our limited personal and organizational resources so that they will be most effective in securing what we *really* want *most deeply*. **PK**

[From MMM #72 FEB '94]
by Peter Kokh

√ <u>space is a place</u> to get clean energy with which to re-green the Earth and raise the standard of living of its impoverished billions.
√ <u>space is a place</u> to find fresh beginnings in culture, in economics, in social and political organization.
√ <u>space is a place</u> to put *some* of our Human *and* Gaian "eggs" outside of our fragile solitary "birth basket"
√ <u>space is a place</u> that will allow the human mind and spirit and body to realize new capabilities and possibilities and thereby reflect even greater glory upon the Force(s) that brought us into being.
We need the unfamiliar challenges of space and raw new world settings to more fully develop the full range and depth of human talent potential i.e. "to be all that we can be", collectively.

[From MMM #74 APR '94]

Mission by Mission from Clementine to Settlement

In FOCUS Editorial by Peter Kokh

What follows *is not, and does not include*, a recipe for making anything happen! For that we need an open-detailed multi-targetted entrepreneurial-political game plan, A sketch of such a *how-to* scenario was presented by the editor at the Space Frontier Foundation Conference in Houston, March 18-20th. Look for "Beyond LunaCorp" in next month's In Focus.

Here we simply "list" the **minimum achievement steps** needed to establish a starter settlement on the Moon to **begin the recovery and use of lunar resources**

(a) to help defray the settlement's own costs

(b) to lay the foundations of an "industrial" space economy

(c) *whether* the "agent" is "government" *or* "free enterprise"
To preview, skip paragraphs in ( ) for the first read through.

Precursor Missions

These are of two rounds:

(a) ROBOTIC ORBITAL & SURFACE MISSIONS
to identify candidate sites on the Moon which will favor the successful undertaking of the outpost's missions.

(b) UNCREWED MISSIONS TO OUTPOST SITE
to help prepare the site in advance of the arrival of the first crew's coming to set up shop and begin useful work.

(a) ROBOTIC SITE IDENTIFICATION MISSIONS:

(Clementine is even now yielding our first global chemical map of the Moon. Its instruments are not maximized to detect polar water ice. The odds are strong that such reserves do not exist in economically significant concentrations, yet their contribution to the success and pace of lunar industrializa-tion is potentially so high that we can not afford *not to know* one way or the other. An intel-ligent choice of the equipment needed for starter enterprises depends upon the answer. *If* useful ice reserves are found, it may dictate a 2-site opening gambit, making more sense to transport any ice to where industrially significant mineral deposits are to be found than vice versa.)

It would take **2 years to design and deploy a 2nd lunar chemical mapping mission**. This effect is the goal of David Anderman's Lunar Resources Data Purchases Act. ["Back to the Moon Campaign", MMM # 73, p. 10]

(There will be a need for further orbital prospecting missions in support of ongoing expansion and diversifica-tion of lunar industry. A radar probe for one, charged with locating 'hidden' lavatube voids beneath the surface. And another with enough resolution to locate atypical resource concentrations derived from asteroidal impacts, e.g. Sudbury-like endowments of nickel, copper, and other strategic metals that are not other-wise present in workable concentrations. Such missions can proceed while, or after, our attention has shifted to establish-ment of the initial industrial outpost.)

(A number of siting considerations are important, but not equally so. Delta V differences (ease of access to and from) of various sites are not of make-or-break significance and come into play only "all else being equal" i.e. as a tie-breaker.)

(Polar access to round-the-month sunlight is overrated as the lunar axial tilt of 1.5° is *not* "negligible" and would require collector emplacement on a tower at least 2,000 ft. higher than all features on its horizon.)

(Limb "equal-access" to both Earth and Farside is also overrated. Due to libration effects, there is a 14 degree swing in orientation monthly. This will be a challenge for planners of Lunar Solar Arrays and has so far been ignored.)

(Scientific considerations should NOT enter into the selection of a site. Paradoxically, science is best served by putting it on a back burner. Ultimately, far more science can be logistically supported overland from a resource-using base on the Moon, than from select on-site camps supported wholly from Earth. For science, patience will pay off; and we *must* insist on this subordination of purposes.)

(For industrialization purposes, the nature and diversity of the local soils are utmost. A "coastal" mare-highland site gives access to both major types. The innumerable sites that meet this qualification can be further narrowed by requiring access to KREEP (potassium, rare earths, phosphorus) splash-out soils (from the impact that created the Mare Imbrium basin) as well. A fourth type of soil which has not been investigated by any of the Apollo or Lunokhod missions is that of Crater Central Peaks which probably represent upthrust mantle materials. Access to such materials are perhaps best left to exploration and exploitation by a supplementary second or third industrial site.)

(In last analysis, there are two approches to site selec-tion. *If* the purpose of the first outpost is only to demonstrate the concepts behind future lunar industrialization, we need be less careful where we put it. *If, however,* we want to pick a site where we can, if all goes right, expand to develop "the" major early lunar industrial center, then we ought to have the foresight to put it within very easy reach of a (complex of) known intact lavatube section(s) for the significant presheltered volumes offered. I favor this approach. While perhaps the vast majority of intact lavatubes are yet to be located and identified and later orbital detective work may locate a much more favor-able site, we do know enough to pick "a coastal-with-KREEP near-lavatube site" which "will do" for our industrial foothold.)

Timeline for Site Selection = one year after the flight of the second generation orbital mapper.

(B) UNCREWED SITE PREPARATION MISSIONS: One or two missions to the selected site to accomplish the following:

(a) GRADING, leveling, trenching and other terrain modification to receive prefab structures from Earth.

(b) BAGGING regolith in bags ready to be piled up against the sides of taller structures, e.g. a multistory inflatable sphere.

(c) CACHE buildup of site-processed ready-to-use resources so the first crew can better "hit the ground running".

1) LIQUID OXYGEN for use as a fuel, air, water constituent, and industrial reagent.

2) IRON FINES magnetically separated.

3) STOCKPILES of other more easily separated mineral processing feedstocks.

(In addition, other helfpful tasks can be done. IF we can fashion simple enough equipment to leach lunar silicon from the soil by reacting it with hydrogen, we might produce and store SILANE, SiH_4, for use as a lunar fuel along with our lunar oxidizer. While less powerful than hydrogen, silane would nonetheless 'extend' the power of any hydrogen brought to the Moon, cutting both import costs and export overhead. The idea here is to aim in the direction of reducing the fuel- cost of sending "people, tools, and seeds" to the Moon to as near that of sending the same items to LEO as possible.)

Developing Needed Equipment.

One way is to induce competition between potential contractors. Each candidate would build a prototype demonstration unit to be field tested on the Moon. The firm with the demo unit that worked best with the least snafus would get the contract to supply the initial production line apparatus.

(While we'd like to know much more about lunar processing possibilities and options than we now do, we must design our FIRST settlement to use those processes we are confident will work with a minimum of trouble. We need to use what is pre-developed *at the time* we are otherwise ready to go. *However,* since we are not now ready to return, it would be foolish and presumptuous to *settle* for what we now know how to do. As far as budgets allow, continued interim research into processing and manufacturing possibilities must be a high priority. Whether it's glamorous work or not, if we don't do a minimum of homework, we will not deserve to succeed.)

Return Structures and Vehicles

The size of the Shuttle Payload Bay is very confining. There is no good reason to continue accepting that limitation. Shuttle-C and other options for boosting larger prefab structures do not require technology breakthroughs, only the will to put together existing elements in new combinations. Zubrin's Moon Direct (compatible with Mars Direct) plans assume this.

(Dr. Zubrin's plan is optimized for short stay science missions and as such is an excellent starting point amenable to further development to fit our purposes. Major shortcomings are the lack of shielding, the lack of pressurized interconnec-tions between the various habitat modules, and the failure to incorporate elbow room via attached inflatables.)

(Another vehicle/hab option is the "ET Compatible". We could replace the STS Orbiter with a second, dry, fully pre-outfitted ready-to-occupy ET-based structure (ETC) No orbital or lunar EVA required), with an additional pair of

SRBs if needed. The harder trick is to land something of that size on the Moon, horizontally. It is doable.)

(Another possibility is that of hybrid combinations of hard-hulled works-packed core modules with inflatable expan-sion space. This option needs Earth-demonstrable architectural and engineering exploration. *We cannot expect to get much done on the Moon if we only have room for a handful of people who have to hot-rack and are tripping all over them-selves with everything they do*.)

(If we are otherwise ready for a return to the Moon, the initial mission should not be delayed pending the readiness of more spacious habitat options. Yet it will be difficult to advance to followup mission stages if such options do not come on line in timely fashion.)

Industrialization begins with industriousness. Industriousness must begin now.

Goals of the 1st Crewed Mission

(After six crewed Apollo missions, a human has yet to sleep on the Moon in a bed, or to walked in 1/6th gravity without a spacesuit. All our brief stays have been in dayspan. No one has 'over-nighted', a feat that will require power storage for the nightspan. But we must not make demonstration of the above capacities the sole requirement of the first mission.)

At a minimum, the first mission must

(a) DEPLOY and SHIELD initial base structures. NOTE: we could pre-land at least some of the base habitat structures and to use teleoperated equipment to cover them with shielding so that they are "ready to occupy" by the time the first crew arrives. Among these advance structures should be habitat, lab, power generation and communications equipment.

(b) POWER STORAGE system demonstration - to allow the outpost to function effectively, doing less energy-intensive tasks, through the two week long nightspan periods. If we do robotically pre-deploy the base core, we could test and demon-strate the availability of sufficient nightspan power before the first crews arrive.

(c) FURTHER PROCESSING DEMOS using regolith that has been pre-sorted in the cache build-up phase that preceded.

(d) FIRST FARM UNIT setup.

(**NOTE:** Some of the vehicles bringing in pre-return equipment can, and should designed as "transformers" i.e. for reuse as surface trucks and coaches. In the early stages, there will be far more payload coming to the Moon than returning, and it will accordingly be foolish to waste delivery vehicles by designing them all to be "reused" rather than "recycled". Such 'amphi-bious' space/surface transformers could better achieve all the purposes of the first and subsequent missions.)

Goals of the 2nd Crewed Mission

(a) DEPLOY ADDED EQUIPMENT, FACILITIES

(b) DEMO MANUFACTURING TECHNIQUES and fabri-cation processes using materials processed during the first mission: Glass composites and sintered iron are top priorities. Optical (window) glass and ceramic products come next. Lunar concrete will be an early option only if economically workable polar water ice deposits have been discovered.

(c) DEVELOP ADDITIONAL EXPORT COMMODITIES (beyond oxygen, etc.)

(d) USE OF DIVERSE HINTERLAND SOILS.

(e) EXPANDED FARMING, use of stored human wastes

(f) IMPROVED RECYCLING beefing up the air and water recycling systems with biological assist

Goals of the 3rd Crewed Mission

(We cannot reasonably expect crews to volunteer to stay indefinitely until we have more than sterile sardine cans to offer them. They would go mad. The use of lunar resources to make building materials for outpost expansion and creation of real elbow room for an order of magnitude increase in both private and communal square footage per person, opportunities for Made on Luna furnishings, artwork, and softening with Grown on Luna plantings is a priority which cannot, must not be postponed without courting disaster and ultimate failure.)

(a) DEMONSTRATE SHELTER-BUILDING KNOW-HOW. Build components and erect them on site relying heavily on materials processed from lunar regolith soils.

(A lot of homework *on Earth* will need to have been done on optimizing a lunar-appropriate modular construc-tion "language" getting the most diversity of layout options from the least number of distinct elements, manufacturable with the lowest mass of capital equipment, and erectable with the least EVA man hours.)

(b) EXPANDED PRIVATE AND COMMUNAL SPACE. Fortunately, neither of these space needs require expensive outfitting, and much of the outfitting can also be done with Made on Luna items and elements.

Goals of the 4th Crewed Mission

(a) EXPAND PLANT and FACILITIES
(b) INDUSTRIAL DIVERSIFICATION
(c) EXPORT DEVELOPMENT
(d) RECEIVE FIRST SETTLERS, informed volunteers for indefinite, open-ended stays.

(It will be time to end any prior discouragement of pair-bonding or family formation. The incorporation, as the base expands, of associated personal of non-productive ages. We cannot tell in an Earthside lab if living on the Moon is benign over the course of a lifetime. We have to get our feet wet and take the plunge without delay. There will be casualties as in every previous human expansion into a new niche. The timorous need not apply.)

Constructive reaction and input is welcome. ***PK***

Show me the person
who has never failed,
and I'll show you a person
who has never tried