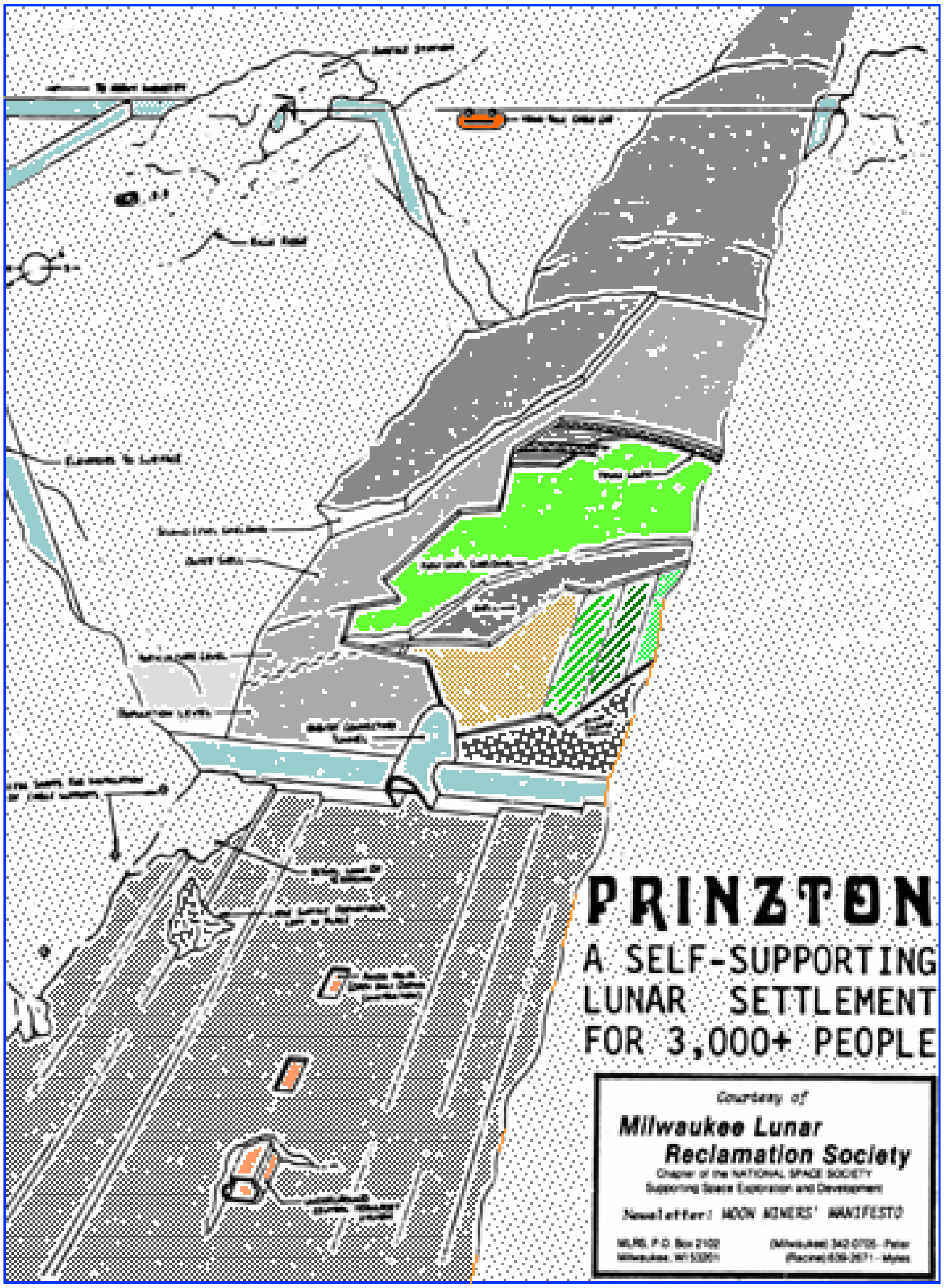
EXPANDING THE HUMAN ECONOMY THROUGH OFF-PLANET RESOURCES

MOON MINERS' MANIFESTO

MMM Classics
The First Ten Years

Year 3: MMM #s 21-30
December 1988 - November 1989



PRINZTON is a 2-level, 3-village settlement in the bottom of a rille valley formed from a collapsed lavatube, near the crater Prinz, not far from the famous crater Aristarchus.

The two levels are intended to step down the air pressure and reduce structural stress. Some 25 feet (8 m.) of regolith cover each of two arched vaults over farming fields above, village area below.

The Report on this award winning entry into NSS' 1989 Space Settlement Design Competition is serialized in MMM #s 26. 27. 28, 29, 31, and 32, beginning on page 31.

The sketch at left shows one covered village at top, a cutaway of the second in the middle, and the prepared "bed" for the third under construction at bottom. Each village has its own day cycle, staggered 8 hours apart, so that workers and staff can man 24-hour factories, schools, and public services around the clock with each working on his/her own "first shift."

Elements of a rille-bottom subway and transport access to the rille shoulder top are shown.

SPACE DEBRIS: OUR SILENCE BETRAYS US

Commentary by Peter Kokh

Articles in recent issues if several space magazines have called our attention to the growing problem of space debris. It is a sad commentary on the depth of our concern, that in each case the writer begins with an alarmist headline only to end up telling us not to worry, to go back to sleeping on the job -- for that is what we have all been doing.

NORAD (North American Radar Air Defense) is currently able to keep track of over 7 thousand tidbits of orbiting flotsam, and it is estimated that there are hundreds of thousands of fragments up there below the threshold for detection, but large enough to do significant damage when and if. But what's the big deal? Between 100 and 600 miles up, to pick a range handy for a back-of-the-envelope calculation, there are over 100 cubic **b**illion miles of space.

The point is that *almost all of this debris could have been avoided.* It is the result of carefree, slovenly house-keeping habits. Quite like our alleged primate progenitors who to this day cannot be housebroken, mankind, in chip-off-the-old-block fashion, apparently cannot be *planet-broken.* We insist on fouling our own nest; in space, it has been business as usual.

Problem-Aggravating Attitudes

Many of us in the space movement also consider ourselves environmentalists (in a good sense of the term.) But we have gung-ho fellow travelers for whom space development and environmentalism seem to be antithetical. Unless we can change the minds of such, we will eventually undercut all our efforts to open wide the space frontier.

Whoa! Let's not rock the boat! Our job is to gather support for NASA and not question how it does things. Oh? The truest friend is one who is not afraid to offer constructive criticism, and does so when needed. Fear of antagonizing those we hold in awe is immature. Wed pride ourselves in being people of the future: *foresight is supposed to be our business.* Unless our advocacy is to be a joke, NSS *must be watchdog as well as friend.*

Just what is at stake? Most of us perceive our number one priority to be bringing down dramatically the high cost of access to space. Continuing to be silent about space debris which could in time make those high costs even higher, is counterproductive. We are equally concerned about the relatively closed status of the space frontier, open only to a proxy elite. It is a prime directive of our shared NSS vision to open the space frontier to general civilian activity; looking the other way while hazards are needlessly increased to the point where insurability may become impossible and access to space becomes akin to combat duty, gives the lie to our earnestness.

According to some aging surveys, we are about evenly split pro and con SDI (the Space Defense Initiative or "Star Wars"). Those who are in the pro column because they feel SDI is the one real chance to increase the volume of space-bound traffic to the point where economies of scale begin to be felt, should be honest enough to admit and accept the very real possibility that unrestrained SDI testing could conceivably render all low Earth orbit space unusable and end up quarantining mankind in our ever less cozy cradle for generations to come. Of course, there might be holes in the debris shield high over the poles. We could always build a spaceport near Alert at the top of Ellesmere Island and launch to high Earth polar orbits!

While it is further down the pike, tourist traffic to LEO is something we'd all like to see and could generate far more traffic than SDI in the long run, *if* the inherent dirtiness of the SDI effort doesn't nip this prospect in the bud.

Sources of the Debris Problem

The offending space flak is generated in several ways:

- jettisoning of final booster stages, of farings and other no longer needed paraphernalia
- use of explosive bolts
- dumping of wastes and garbage by crewed vehicles
- rare but increasing collisions, detonations, and impacts

NSS should begin working with aerospace engineers -- **a workshop** might not be a bad idea -- to come up with ways to cut down such practices, or better yet, to avoid them altogether by better design. Our RVs (Recreational Vehicles) on Earth have holding tanks for wastes. Should not our spacecraft also?

As vast as it is, LEO-space is no more a bottomless sink than are Earth's oceans. Farings could be kept, moved aside, to be extended outrigger style in a "dead man's" device to increase drag and hasten deorbiting of derelict satellites. Perhaps this suggestion is naive but if it spurs a better idea, it serves a purpose.

A World Space Access Authority?

Maybe it is time for a world authority to set design standards and heavily tax improperly designed boosters, satellites, and other traffic to orbit. Mission profiles must be looked at. Debris impact statements should be required for a permit to launch. There could be incentives for salvage, but realistically, most ofthe mess already generated cannot be easily cleaned up. Rather, our attention must be on ways to avoid worsening the situation. Yes,it's a lot of unwelcome hassle. But in the end, we'll be glad we faced up to the challenge.

The problem is not going to go away, and we in the National Space Society *owe it to our own dreams* to come to grips with it even at the risk of becoming unpopular. **MMM**

Colonist's I.Q. Quiz: Humans in Deep Space

Questions

[1] Before Apollo 8's envelope-bursting trip out to the Moon, what is the furthest humans had ventured off the surface of Earth?

[2] We all know the names of Borman, Lovell, and Anders, the first three humans out to the Moon. But who was the first to orbit the Moon 'solo'?

[3] Of the 24 men out to the Moon (3 of them twice), who came the closest without landing?

[4] Which 3 have been the furthest from Earth?

[5] What is the furthest from Earth that anyone has 'gone for a walk' outside their spacecraft?

[6] Was anyone exposed to a massive solar flare?

[7] Who holds the human speed record in space?

[8] Who was the first civilian in space?

[9] Who was the first paying fare in space?

[10] For which of the nine Apollo Crews to orbit or loop the Moon was the greatest portion of the farside visible in sunlight?

Answers

[1] 850 miles by Conrad and Gordon in Sept. 1966 in the Genini 11 craft boosted by Agena 11.

[2] John Young in the Apollo 10 Command Module.

[3] Tom Stafford and Gene Cernan in Snoopy, the 1st Lunar Module out to the Moon (Apollo 10), in a dry run dip to within 10 miles of the surface.

[4] When Lowell, Swigert and Haise rounded the Moon on the landing-aborted Apollo 13 mission, they where 248,655 miles from home.

[5] Worden (A15), Mattingly (A16), and Evans (A17) all had to go outside to retrieve film cannisters from service modules. In each case they were about 200,000 miles out from Earth and 40,000 out from the Moon at the time.

[6] Pavel Papovich, Yuri Artyukhin in Soyuz 14 from July 5-8th, 1974. However they were protected by being within the Van Allen belts.

[7] The returning Apollo 10, Stafford, Young. and Cernan, plunged into the atmosphere at 24,790mph.

[8] Konstantin Feoktistov, the first scientist, and Boris Yegerov the first physician both on the Voshkod 1 flight October 12, 1964.

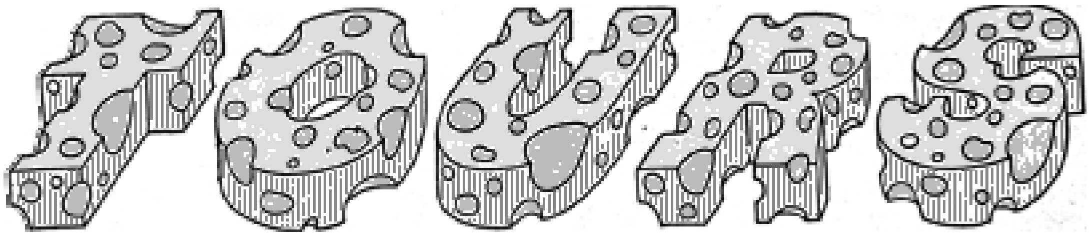
[9] The new President of the National Space Society, Charles Walker, electrophoresis expert with McDonald Douglas who paid NASA $100,000 for his 'ticket' aboard Discovery on the STS41D mission, Aug. 30 1984. He had the same role on STS51D and STS61B. Total time in space 13 days.

[10] For the Apollo 8 mission the Moon (nearside) was just past 'new', almost totally dark, and the farside just past full, almost totally sunlit.

MMM

Earlier than you think

Lunar Overflight



by Peter Kokh

To be honest, it will be a long time before you can go to your local (or any other) tourist agency and book a two week tour on the Moon. Even after we have returned to Sol III B to set up permanent bases and installations, even after actual settlement has begun, facilities for tourists will be a while coming.

All the same, within a decade of the start up of tours to LEO (Low Earth Orbit), flyby "overflight" tours out to the Moon will begin. All the talk of micro-gravity processing aside, the real gold mine in space may well be tourism, once new vehicles bring access costs down. Now there is simply not that much of a jump from tours to LEO to following in the trajectories of Apollos 8, 10, and 13 which took three crews out to the Moon without landing, as in the classic novel by Jules Verne. In brainstorming ways to bootstrap an economically profitable return to the Moon, would-be entrepreneurs should not overlook the comparatively low threshold to lunar overflight excursions.

Perhaps you think the prospect of paying good money for a lunar odyssey *sans* 'Moonfall' would be too much of a tease and disappointment to attract much business? Read on. We offer this future fiction scenario set 20 years from now in 2008.

My Flight on the A.F. Jules Verne

by Simon Cook

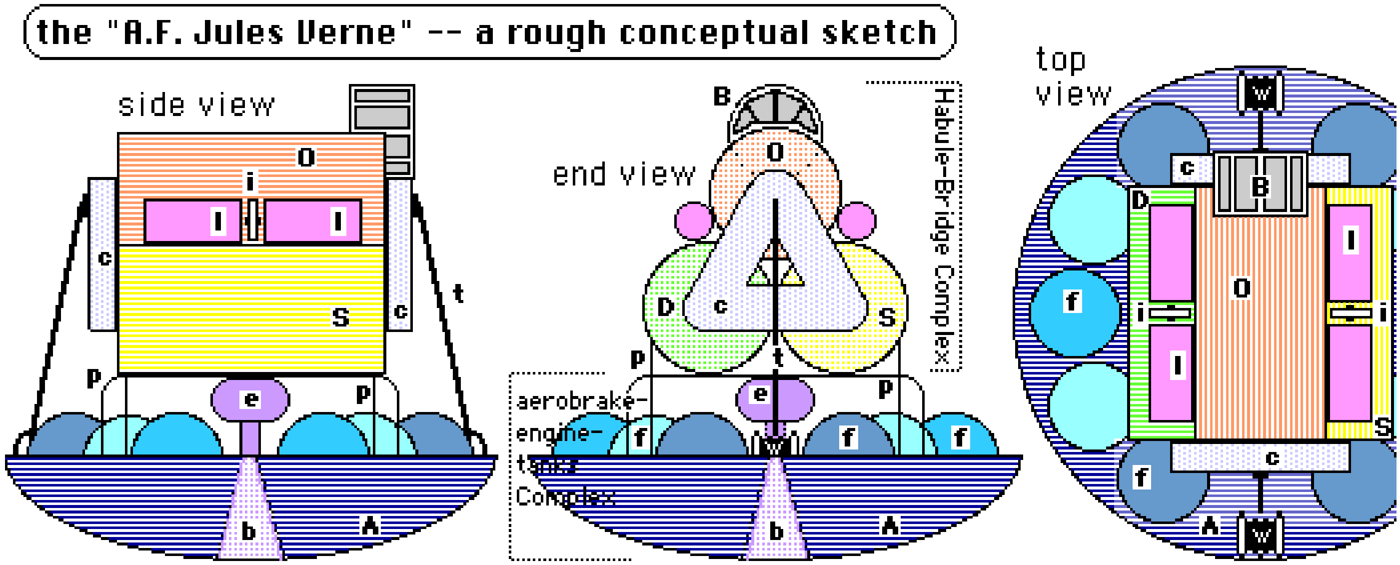
The sleek “silver sliver” of our Boeing 8O8B *Columbiad* gently eased off the rocket sled trolley that served as its 'first stage' at the end of its track at Jose Marescal Aerospaceport just north of Quito, Equador and began its streak for orbit. (At 9500 ft. elevation and smack on the Equator, Quito had became the first civilian gateway to space, serving both the Americas. Similarly advantaged, 8600 ft. high Nairobi fills the same need for Europe, Africa, and western Asia. The third gateway, serving East Asia and Australia is Singapore whose sea-level handicap means smaller payloads and fewer passengers to orbit.)

Within the hour the *Columbiad* pulled up to the new Orbitel *SupraTropicana,* owned jointly by the three gateway aerospace-lines (Equatoriana, Aerospace Kenya, and Singapore Aerospacelines), Terre-Lune (say tehr' loon') Excursions Ltd., and Motel 6 ("the only luxury you want to pay for is the view”). At 1000 km or 600 miles up, the *SupraTropicana* is the highest orbiting of all the man-rated orbital facilities yet built. This avoids the need for periodic reboosting caused by the drag of the tenuous upper atmosphere, but the real rationale behind the orbit choice is that following a zero inclination equatorial orbit, the guests of the orbitel would otherwise see only a narrow swath of the Earth below, repeated over and over - a slice through South America, Africa, Indonesia, and lots and lots of water. But at this higher altitude, at least the entire tropics lie within the orbitel's horizons.

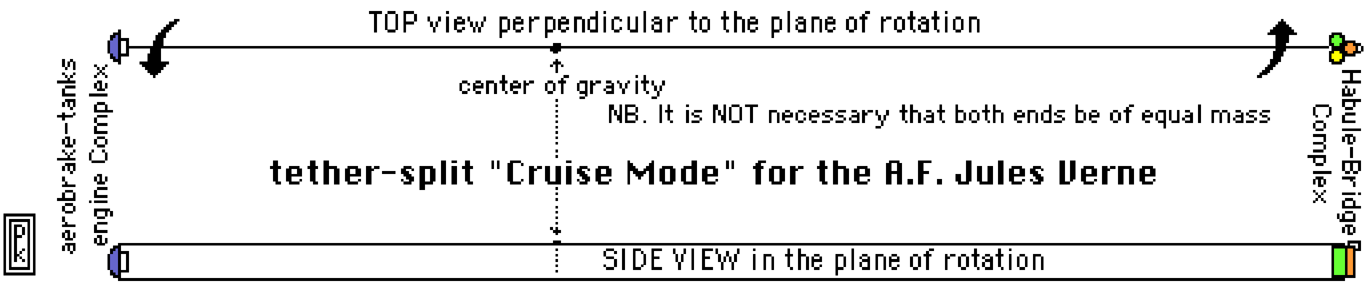
A few hours in the *SupraTropicana* calms us down from the excitement of the boost up from Quito, and allows us to get our space-sickness medication adjusted. We all enjoy enjoy the Olympian view.

The 36 tourist class passengers and the 12 crew class (we get a fare break for one time service as ship personnel, after a bit of training, of course) are welcomed aboard Terre-Lune Excursions' flagship, the *A.F. Jules Verne*, by its permanent staff of two, the captain and first officer. This arrangement (a crew class in which paying passengers assist) drastically cuts overhead and allows TLE Ltd. to offer more for the money. At these prices, that's a must!

The *Jules Verne* is quite a ship. The 'A.F.' stands for aerobrake ferry. A ferry is any spacecraft capable of plying a regular route without, however, ever landing anywhere. It is meant for space alone. Being equipped with an aerobrake means it can return from deep space and use the friction of a low-angle graze of Earth's upper atmosphere to shed enough velocity to skip back out neatly into the desired orbit. As the aerobrake apparatus weighs a lot less than the extra fuel, the



KEY: A Aerobrake -- B Bridge -- b engine bell -- c inter-habule concourse --
D Diner-Lounge Habule -- e rocket engine -- f fuel tanks --
i anti-twist inertial orientation flywheels used in cruise mode --
l life support equipment -- O Observation-Lounge Habule --
p platform to nestle the Habule complex -- S Sleeper-Lounge Habule --
t tethers -- w winch reels for tether-deployment in cruise mode.



ship would otherwise have to carry for deceleration, an A.F. has more capacity for cargo and passengers, and that after all is what pays the bills.

She is a beauty -- once you come to appreciate the elegant efficiency of her design! For she is ungainly next to the transatmospheric *Columbiad* and doesn't at all remind one of the great spaceliners conjured up by science fiction writers.

At the 'bottom' is the gentle curve of the wide aerobrake shield which has shutters that open to expose the exhaust bells of the rocket engines. [ILLUSTRATION] Above the aerobrake, are the engines, fuel tanks, and the umbilical tether-cable reel and winch. On a platform above all this sit two of the three cylindrical habitation units or 'habules' (the initiated simply call them 'cans') built by Occupod and brought up on the Hercules Heavy Lifter. One of the habules is a sleeper-lounge whose name plaque reads Moonlight Sonata. The other is the diner-lounge with the pretentious French name (no reference to the cuisine!) La Vache Sautante (say la vahsh' soh tahnt')("the jumping cow").

Above and nestled between these is the third habule, an observation-lounge named Claire de Lune ("moonlight") with roll-top shutters over vista windows along its topside, used during the lunar over-flight, and petal-shutters over the end cap windows which offer views of the receding Earth and approaching Moon on the way out, vice versa an the way back. (Why the ship cruises sideways you'll see shortly.)

Concourse between the three habules is via a triangle of pressurized passageways at either end, the modest bridge being attached to one of these. So this gives you some idea of what the JV looks like during power mode, during the lunar overflight in which it is upside down to afford the fullest view, during aerobrake maneuver, or buttoned up for flare protection, aerobrake towards the Sun. But this only covers a few short periods.

For most of the three day cruise out to the Moon, ditto on the way back, the ferry is in cruise mode. The habule-bridge complex is then released from its platform, while remaining attached to it by a tethered harness attached to the ends of the observation-lounge (the top one on the stack). The complex is then rotated so the bottom two habules are furthest from the aerobrake-engine-tank complex, and the tether is reeled out a couple hundred meters, while the thrusters on the engine complex start the counter-weighted system slowly rotating at a rate that provides 1/6th gravity enough to make the passengers and crew comfortable and at the same time give them all a chance to experience what being 'on' the Moon itself would be like, vicariously. On the return, however, with the lunar experience behind them, the tether-split ferry spins the first half of the return at a rate twice as fast to give all a foretaste of Mars, and finally spins up to full Earth-normal gravity to ease their adjustment going home.

Hot-racking is the rule on board, no exceptions. Each berth must be shared by two passengers in rotation. Morning people like me, those who find getting up easy if not altogether a joy, sleep first from 1600-2330 hours ship time. We can retire as early as 1430 but must vacate the berth promptly so the crew class passengers can get them ready for the next shift, the night people, those who find getting up distasteful. They have the berths from 2400-0730 but may tarry till 0900. (A surplus of either 'morning' or 'night' people is handled first by volunteers and then if necessary, by a draw.) From 0800-1530 everyone is in either the diner-lounge or the observation lounge. Ship time is set so that the periods when everyone is up coincide with departure from LEO, the lunar overflight itself, and the final return approach to Earth. Time-sharing the facilities allows the ship to carry twice the number of passengers it could otherwise handle, or to put it another way, charge only half the exorbitant fare it would otherwise need to show a profit.

Terre-Lune Excursions Ltd. goes all out to provide a real 'lunar experience' and I do mean all out. Providing 1/6th G on the way out is only part of it. No opportunity to enhance the atmosphere is overlooked. The three habules are all furnished with materials that the early lunar settlements should be able to fabricate from the soil. This even goes as far as the color scheme: only those coloring agents, metal oxides and ions, that the early settlers will be able to extract economically are used. Furnishings are thus mostly of glass-glass composites (Glax™), sintered iron, ceramics, softened by crudely processed cotton, and fiberglass fabrics. Except for ceramic glazes, stained glass and green plants provide most of the color. This decor is called 'Lunar Dawn' in Terre-Lune's promotional brochure. (One of the crew class passengers is a settler-recruit who cheerfully explains all the options open to the settlers in adapting to their chosen home-to-be; naturally, I spend a lot of time plying her with questions.) Add the 1/6th gravity, and those on board are getting a very genuine preview of life in the early settlements. And you thought all we were paying for was an up-close view of a monotonous expanse of cosmic splashprints! But more about that later.

I should say something about the food in La Vache Sautante diner. Even here an opportunity to set the stage is seized. When tourists sign up for a cruise, they are all given a list of available food items and asked to check their preferences and preferred combinations and to select from a list of menu items accordingly. Only those food items that an early settlement might expect to raise in its own farms are included on the list. So the variety available excludes all the more exotic choices to be readily had on Earth. Chicken, rabbit, or cavy for meat and that only as an accent, talapia for fish, a half dozen vegetables and fruits, some herbs and a little in the way of spices. Beverages include only water, vegetable and fruit juices and a few simple fruit juice-added seltzers and herbal teas. But this limited selection gives a healthy and balanced nutrition and variety enough. Now the ship cannot stock to meet every combination of whims. So each passenger, for each meal gets to order (and check off the list) only from the food he/she has preordered before boarding. Towards the end of the cruise one’s selection becomes limited to what is left. The wiser passengers reserve some treats for last.

Even the games and reading materials

aboard are in a form reproducible by an early colony. Now to be sure, some of this 'lunar experience' could be reproduced on Earth, but out here with no distraction or escape, plus the low gravity, the total effect is intense.

Finally, after three full days previewing the lunar frontier, we are approaching the old girl herself. Our anticipation is high. This is, after all, the climax we paid for. Slowly, the thrusters despin the tether-split ship and the spring loaded tether reels in our habulebridge section. Once back together and secure and gravityless, the ferry turns so that its top, the still-shuttered vista windows in the ceiling of the observation-lounge are kept Moonwards.

As it happens on this particular cruise, the Moon is between the Earth and the Sun, or 'new' and the nearside is dark. Once we are almost opposite the limb and the Sun is off to the side, the shutters open just in time as we approach the sunset terminator now over Mare Orientalis, the great bullseye basin on the western limb. We are still about 800 miles above the surface at this point, but the long evening shadows add dramatic relief to the wider field of view below. Farside is fully illuminated for overflight. What a treat!

But I am getting ahead of myself. Before the shutters are opened, those of us who want a filtered experience are fitted with special heads-up display helmets, a spinoff of military technology thanks to espionage which had made continued classification of the technology a joke. These smart helmets scan both the field of view and the direction of the eye's focus and then neatly yet unobtrusively appear to overprint on the lunar landscape the names of whatever features catch your attention for more than two seconds. The heads-up display also gives the estimated ages of the more prominent bright-ray craters we see, as these fascinating features are far younger than the rest of the 3 1/2 to 4 billion year old surface. With the helmets to provide information, silence is requested and expected during the overflight. Yes, pointing is allowed!

A few refuse the helmets. They want to be fully absorbed in the raw experience of the awesome magnificent desolation of the lunar terrain below (or is it above?). Terre-Lune encourages direct observation, that is to say they discourage preoccupation with photography. The ferry's own cameras are making a very complete record of the whole overflight and can be prorammed to pay particular attention to prespecified features. Videos and slides and prints of this coverage can be purchased from the company for a low fee. Cameras are allowed but we are urged to use them to record on board life, and to keep them shuttered during the overflight itself.

We pass over the Mare Ingenii-Thomson crater area where robot rovers are even now surveying the site for the proposed Farside Advanced Radio Astronomy Facility (FARAF). Someday this ferry and others like it may be delivering electronic mail to FARAF, as a relay satellite at the L2 Lagrange point behind the Moon is frowned on. As planned, this is the very lowest point or periselene of our overflight and we are skimming just 50 miles above the surface. Even though there are no other clues to the scale of what we see, you can tell we are closer by the accelerated rate at which the scene is whizzing by.

Then we pass over the what is easily the most striking feature of Farside, the crater Tsiolkovsky with its very dark mare-filled floor and bright massive central peak. Twenty years ago, crater central peaks were unnamed. Now they are given the first name of the person for whom the crater is named, where applicable. So in this case, we are looking at Mt. Konstantin.

We have just been informed that the Jules Verne is about to launch a resupply pod destined for one of the nearside bases. This one contains medical supplies, some requested seeds for the farms, specialized tools, and other low weight high value items. Such cargo drops help defray the cost of our passage and perform an invaluable service for the pioneers below.

All good things come to an end, they say, and so we approach the eastern limb at Mate Smythii and the sunrise terminator, and there above the rugged morning-shadowed horizon, Voilà, the Full Earth which so rivets our attention we forget to take a last glimpse at the moonscape below before we slip past the terminator into darkness. Reminded, we now scan the inky blackness below each intent on being the first to catch site of the beacon at Base Two in western Mate Crisium before the vista window shutters close and we revert to the tether-split cruise mode for the 'downhill' coast home.

The next few hours finds a few talking excitedly, sharing their private experiences. But most of us are unusually quiet. There is a definite feeling of anticlimax, perhaps a hint of mild depression. But I think the bigger part of our complex mood is simple silence, in an attempt to absorb, assimilate, and relish the flood of visual input.

Not all cruises aboard the Jules Verne are like this one. Some are timed with either the waxing or waning Half Moon (and Half Earth!) None are timed for Full Moon as that would mean that all of the farside would be invisible in the darkness and everyone wants to see some of that portion forever hidden to Earth-bound eyes.

But then there are talks on Moon-Mars differences to go with the Marslike gravity now provided for ambiance, and we begin to come out of our withdrawal. A ship-board wedding between two of the passengers certainly helps! To the familiar lilting strains of Christopher Cross's classic 'Arthur's Theme' (and its great refrain "When you get caught between the Moon and New York City, the best that you can do is fall in love"), it is an unforgettable moment.

The closing portion of the cruise features talks and discussions about the disturbing state of the environment on the almost deceivingly beautiful globe slowly growing ahead beyond the petal-windows at one end of the Claire de Lune. The captain draws our attention to subtle indications we otherwise would have missed of growing desertification, recently clear-cut tropical forest lands, and heavily polluted oceanic currents. I begin to see the deeper significance in the name of the cruise line. This has been not merely a trip 'from' the Earth to the Moon, but a rendezvous with both.

As in the cruise mode on the way out, our axis of rotation points parallel to our path. At last, still four hours out, we come out of cruise mode spin and secure for the aerobrake maneuver, half of us in the berth restraints, the others strapped in reclining lounge chairs. It is a nervous and tense moment for most of us. It may be routine for the Jules Verne but every last one of us signed on green.

Suddenly the g-forces we feel ease and we free-fall back out to the Orbitel. The Boeing 808B is still docked, awaiting out return, with no other assignment during the past week. Her crew and the staff of the SupraTropicana quiz us with an ill-supressed hint of envy. Yes, it's been the experience of a lifetime, and with this sneak preview under my belt, I've lose the last of my hesitation. I am definitely going to apply to the Settler Recruitment Office the first chance I get. I'm going to go back! **MMM**

Moon Miners' Manifesto – # 22, February, 1989

LUNAR ORES

by Stephen L. Gillette Ph.D.

[The writer, a consulting geologist from Pasco, Washington and who receives MMM via Seattle L5, offers the following comment on MMM # 9 (Oct '88) "Colonists' IQ Quiz", question 5:]

The "fact" that there are no enriched deposits on the Moon is merely a bit of conventional wisdom. Granted, the Moon does not have the bewildering variety of processes, many water dependent, that Earth does. Nonetheless, not all ore-forming processes require water, and such processes will work just as well on the Moon as here. Examples include:

(a) Layered igneous intrusions, in which crystals settled out of a large body of cooling magma in successive layers; the Bushveld intrusion in South Africa, source of much of that country's mineral wealth, is a classic example.

(b) Liquid immiscibility in a magma, in which the magna "unmixes" into two separate liquids, like oil and water. This can happen in silicate-silicate, silicate-oxide, and silicate-sulfide systems, and all are potentially of economic value.

In addition, although Earth-type hydrothermal deposits are not likely on the Moon, because of the absence of water, analogous late-stage magmatic fluids might occur with halogen or sulfur-rich compositions instead. For would-be lunar miners, laboratory investigations of anhydrous silicate melts is an obvious step we can take right here on Earth, to indicate what might occur. Earth magmas always contain some water, and so we don't have a good feel for how water-free melts might behave.

We must remember that mineral deposits are rare on Earth, too; we've been scouring Earth for millennia, and are still finding new ones! The Moon, although simpler than the Earth, is nonetheless a much more complicated body than is sometimes realized, and it is virtually certain to have local anomalous concentrations of useful materials. **< SLG >**

EDITOR'S COMMENT: I had been aware that the lunar magmas cooled differentially and that various immiscible phases settled out, but was of the impression that the mineral variety thus afforded was not of much economic significance. It is good news that such is not the case and that the Moon's apparent homogeneity may be somewhat superficial.

This gives increased importance to both orbital and in-the-field prospecting, which will certainly make the Moon a far more interesting and varied place to live and work, possibly supporting a number of small settlements. Also important is the possibility of Sudbury-like 'astrobleme' deposits of meteor-delivered ores such as nickel and iron.

Orbital resource-mappers and a more careful photographic survey may give some clues as to where to look. At the same time it should be kept in mind that at any one given site, as much as half of the surface material is locally foreign -- imported as splashout debris from impact sites elsewhere on the Moon. Present mining plans are only for loose surface layers. When we start probing below this loose regolith, exciting finds may be made.

1st EXPORT$

A 1988 SSI Brainstorming Workshop

Reported by Peter Kokh

The Team

In MMM #20 "STATION MATE" we reported and commented on Space Studies Institute's 1988 brainstorming Lunar Systems Workshop session that addressed commercial and entrepreneurial opportunities in Low Earth Orbit (LEO). In this article we'd like to report on the work of another team at this same workshop, this one addressing Lunar Surface Operations. The team budded a “Quick Payback” Subgroup consisting of Edward Bock of General Dynamics, Gregg Maryniak and Rick Tumlinson of Space Studies Institute, Robert Temple of Pacific Institute, and Brian Tillotson of Space Resources Associates of Seattle. The group's goal was the same: 'to create one or more scenarios or business plans for the productive use of lunar materials', guided by the “philosophy that independent, profit-making space businesses could provide a robust, non-reversible course into space.”

Goal: Identify Profitable Opportunities from robotic missions to the Moon

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

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

Information from Teleoperated Rovers

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

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

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

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

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

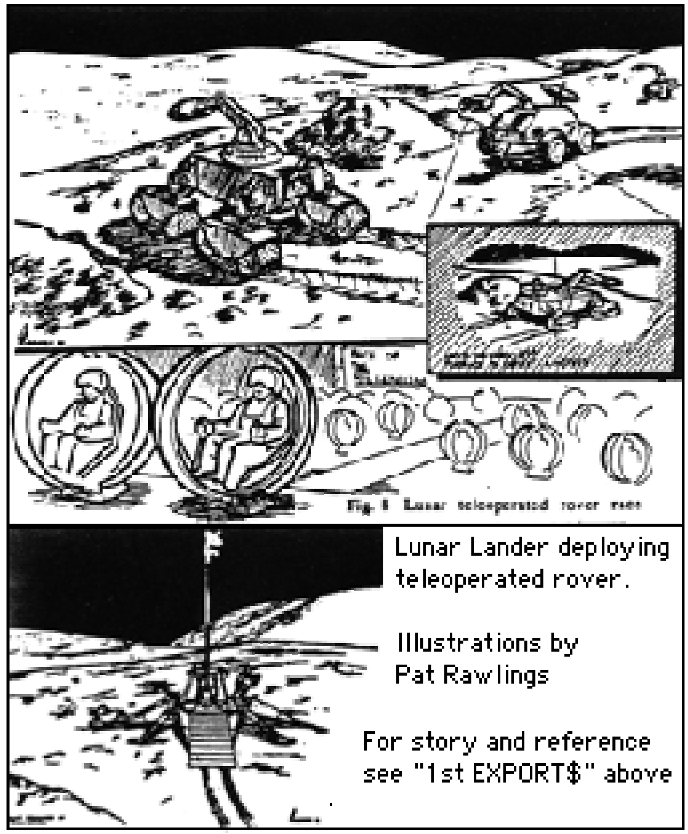
The value of such products on a back-home market is highly speculative and depends almost entirely on demand. The group optimistically hopes for a sustainable demand for such coins and jewelry in the $300-500 per carat range. [By way of comparison, this is over 100 times higher than the going rates for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

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

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

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

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



Lunar Lander deploying teleoperated rover.

Illustrations by Pat Rawlings

For story and reference see "1st EXPORT$" above

1st Souvenirs

Lessons from Mt. St. Helens

By Peter Kokh

Trash to Treasure - May 18, 1980 started out to be a day of spectacular demonstration that human conquest of nature was but a veneer. That was the day that Mount St. Helens blew its top. In time, however, enterprising Washingtonians put the unwanted inches of white ash that buried much of their state to an amazing variety of uses.

To be sure, much of this ash was merchandised tongue-in-cheek. The same people who once fell in love with cute little "pet rocks" at $5 apiece, were now lining up to buy MSH ash for "pet food" for these critters. The ash found its way into novelty gift soap bars, ash ant farms, candles, terrariums, gag salt, pepper, and ash shaker sets, and bean bag chairs.

Ash-filled souvenirs soon appeared such as paperweights, pens, good luck charms, hour glasses, etc. But what caught my interest immediately was the way in which serious local arts and crafts people quickly found ways to express themselves in this suddenly abundant ash-cheap new material. Potters, glassmakers, sculptors, and painters all began experimenting with the stuff and producing items of exceptional character and beauty.

Lessons for early lunar entrepreneurs

What in the universe, you ask, does this have to do with the Moon? The answer should jump out at you. The previous article, FIRST EXPORT$, highlighted the SSI brainstorming idea that the glass nodules and iron fines in the tailings from the lunar soil run through a pilot liquid oxygen production plant could fetch a high price on Earth if turned into novelty jewelry and coins 'made-on-the-Moon'. The assumption here is that the vast bulk of the ash-like soil could not be turned into comparable profits. Not so!

'Made-on-the-Moon' Fad

I do endorse the glass jewelry and iron coin idea for an icebreaker lunar enterprise since the 'made-on-the-Moon' aura will definitely add extra market value to the extraterrestrial origin of the material itself. BUT the artistic quality of such 'machine-made' trinkets and the number of people who will want to pay the price both work to limit the potential of this gambit.

Lets See What Earthbound Artists & Craftsmen can do with Moon dust & rocks

This “Junior Chamber of Commerce” effort should be immediately followed by a bi-world enterprise in which a group of human artisans commissioned by the venture company fetching the lunar soil, would turn the common 'Moondust' into objects of more genuine beauty, right here an Earth. The price of their works could be kept high by the simple device of using the Moondust as an accent, a garnish, an ingredient adding striking character to objects the bulk of whose materials are Earth-derived, The results would be none-theless authentic and certified LUNAR SOUVENIRS. To illustrate:

- Moonscapes created with lunar soils of various shadings in an earthly glass-glass sandwich (wall-art, jewelry box lids, pendants, votive candle glasses etc.)
- Fine terrestrial glassware (bridal registry quality or prestige barware) with etching like patterns made with lunar fines.
- Decorative mirrors, clock faces, and other items made similarly.
- Fine earthly china and pottery in which Moondust is used as a striking glaze accent. Lamp bases and glass shades, candlestick holders, book ends made similarly.
- As colored glass fiber combined with earth glass matrix in striking and illustrative glass-glass composite (GLAX*) creations from paperweights in 1x4x9cm '2001' monolith style to luxury door knobs and pulls, 'Moon-pearl' necklaces and earrings, abacus beads, and prestige desktop name plates.

And this is just a starter. Homework can be done now, both with MSH ash and using some of the lunar simulants available at $1/lb. The possibilities are far more numerous, the attainable quality higher, and the market far less shallow for items made-from-Moondust-by-an-artist-on-Earth than those made-on-the-Moon-by-machine.

[Special thanks to my sister Mary Wegmann and to Jack Estes both of Peninsula College, Port Angeles, Washington and to Carla Rickerson, head of the Pacific Northwest Collection, University of Washington Libraries, Seattle, for their research assistance and suggestions.] **MMM**

HAIR

On the Moon, Shorn Hair May be Zealously Saved for Various Uses

Py André D. Joseph and Peter Kokh

In the early lunar settlements, many of the arts and crafts materials we take far granted will be scarce, if not altogether unavailable. Ceramics, glass, and sintered iron will be the probable mainstays for the Lunan artisan.

A scarcity of “soft” art & craft stuffs

Byproducts of the colony farms such as wood, pulp suitable for making craft papers, natural resins, etc. are not the easy answer. All such items contain about 50% exotic elements - lunar sources of the hydrogen and carbon components of organic matter may have to be supplemented with imports at great expense (the major savings in on-Luna agriculture will come from using lunar oxygen for the other 50%). There will be considerable economic incentive to recycle all agricultural 'waste'.

Some such products, however, might well do temporary duty as craft materials for children, for example corn cobs and sheaths, as such 'works of art' are seldom long treasured and could be eventually recycled. But permanent withdrawal of such expensive organic matter from the biomass cycle will perhaps be all but taboo and governed by strict regulation.

Recycling in lunar and space settlements must be very thorough to be effective. The penalty for not pursuing this religiously would be a much lower standard of living for the settlers. A greater portion of the income earned from the settlement's exports would then have to used to replace squandered volatiles, instead of for badly needed items to make life a little less harsh, or for imported volatiles intended for biosphere growth.

Making an exception for hair

A point of diminishing returns will be reached, however, and it would serve no purpose to carry recycling efforts to suffocating extremes. We would like to make the CASE FOR AN EXEMPTION at the outset. Let us decide beforehand, that any settler has the right to keep, without penalty, his or her own shorn hair 'for the purpose of self-adornment.'

Hair in the History of Arts & Crafts

Hair? Yes, the history of folk arts & crafts shows that shorn hair can be used in many ways that will make the edges of frontier life just a little bit less rough. To be sure, hair is not a widely used material in today's sophisticated craft scene! But this is not the only art and craft area in which early Lunans would do well to research the folk ways of times gone by.

Our first suggestion is quite obvious. Young girls could let their hair grow quite long. Their locks, when finally cut, could be made into falls, braids, and wigs that they could later don for dress-up occasions as blossoming teens or as mature women. (Young boys could do the same, if distinctively masculine styles of managing their long hair were used: turbans, anyone?) Even settler recruits might adopt as an honored custom the practice of letting their hair grow out, to be shorn later upon arrival in the settlement.

Hair as a macramé stuff?

Such shorn hair could also be done in macramé style with made-on-Luna beads and rings, and first worn in sort of a 'coming of age' event. This would all be but one small item in an increasingly distinctive Lunan culture. Hair based macramé could be used as well to fashion tasseled head bands and belts and interesting shoulderettes or shawls.

NSS Chapters Administrator Aleta Jackson ['89] points out that the Romans wove long maiden hair into luxurious ropes. These could be used for waist sash cords, purse handles, sandal uppers, etc.

Artistic use of short clippings!

We take for granted that in early adulthood and for most of one's life, frequent haircuts will probably be the rule. *SAVE THOSE CLIPPINGS!* They can be caught as they drop and carefully sorted by color.

In the past, such clippings have been successfully ground up and used for craft pigments and stains (the characteristic palette of available colors will be small). 'Hair painted' home-fashioned shirts and blouses, ties, skirts, and hankies etc., could become a distinctive settlement craft much sought after by tourists from Earth.

In the past medium length clippings have been painstakingly arranged in inlay and mosaic 'landscapes' and 'paintings.' Usually, the motivation behind such time-consuming work was to provide a treasured momento of a beloved departed one. But no matter; the point is that it can be done!

Hair as a composite stuff

Hair waste has also been combined with a resin to make rich looking beads and buttons. Even those combs which are worn by women to keep their hair in place could be made of their own shorn hair!

Recycling as the last resort

What about shorn hair unsuitable for any of the above self-adornment uses? This can either be placed in the appropriate compost bins or used as doll hair or stuffing, again to be ultimately recycled (unless of museum-bound quality!).

REFERENCES:

The Milwaukee Central Library's Art and craft reference collections contain only a few entries on the use of human hair but these seemed promising enough to warrant this article. We are sure that a more thorough search of folk customs worldwide would bring to light additional interesting possibilities.

NOTE: Frontier Hair Cosmetics

While on this topic, we must keep in mind that the preparations available (and allowable!) to Lunans for hair care will be almost certainly limited to natural, minimally processed ones. However, this is all the people of earlier times had to serve their needs. **MMM**

Of Milestones and Goals

Commentary by Peter Kokh

Milestones and goals are very different things. We equate them or reduce them one to the other at our peril. Landing men on the Moon and returning them safely to Earth was a milestone. Milestones don't have to make sense of themselves, but must be judged by how well they advance a goal. If all we hole before ourselves are milestones, one after the other, it becomes all too easy to call a halt, to take a forever-rest, to question the sense of it all. In the space movement we have never lacked for milestones, only for goals.

After Apollo's failure to generate its own follow-up (as milestones adrift from goals cannot do) many counseled (and still counsel) an *incremental build-up of the lacking infrastructure.* And so we are now in pursuit of a second-guessed series of milestones: the shuttle, the space station, the man-rated orbital maneuvering vehicle etc. There is no argument about the need for each of these, but only about how well each can actually serve to further a silent goal unshared with the nation as a whole when we allow each to be designed without reference to that goal.

The movement today is to invest the next milestone in the series, a permanently manned Moonbase, with the aura and dedication deserving of a goal. We set for ourselves a trap! We must stop playing the incremental game. Incrementalists are in control at the moment, in our own Society and elsewhere. It is time to strip their philosophy of its stolen garments and expose the empty nakedness underneath.

A Moonbase, to be sure, would be an exciting development. It certainly involves a more substantial 'presence' in space than we have today, But defined as such it is not likely to go beyond the stillborn limits of the model that some -- all too many -- hold up for emulation: that of the Antarctic base. The reasoning given in this self-delusion is that such a base would be a foot in the door and the rest will follow. Apollo was a 'foot in the door' -- and nothing followed. A similar sterile result would be inevitable if this nation were to adopt "a" Moonbase as its goal.

It is necessary to point out that after all the decades we have spent in Antarctica, a continent that holds the bulk of the world's fresh water in its ice cap, we still import all the base's water from New Zealand. We have learned to survive in Antarctica, but we have not even tried to learn how to live in that land *on its own terms, in a self-reliant way.* Our goals in Antarctica have been pure detached science. On the Moon, despite hopes for more, budgetary restraints would confine a Moonbase to the same purposes. Plans for pressing lunar resources into service, even to partially defray costs, would be an easy target of budget cutters.

We would do better to ban the phrase "Moonbase" from our vocabulary. What we really need is a *LUNAR RESOURCE STATION whose principal function is to demonstrate the feasibility of self-expansion using lunar resources,* i.e. to begin learning to 'live off the land.'

Continued lunar science will be vitally important to serve this purpose. An ever more thorough understanding of the Moon's past history and more complete knowledge of the present mineralogical distribution will be essential if we are to use her resources to best effect. But it is not necessary to wait upon further science (beyond a *badly needed lunar polar orbital resource mapper precursor mission*) to begin that development. What we face is the *choice e between a science-only base at the cost of billions,* while people are starving, *or a station to initiate economic payback, at which even more science can and will be supported at a relatively small incremental cost.*

It is not enough to provide a shelter for scientists so that they can titillate their curiosity, and ours, and then return home. Our purpose must go well beyond this to make the Moon *a second human world.* To this end our *milestone station* must have the capacity and equipment to make substantial progress in learning to use the raw materials on hand in the lunar soil to support beachhead expansion in a bootstrapping manner. *If expansion is to be an afterthought* (and the term 'Moonbase' risks just that) *it well end up being a forgotten dream* and you can carve that quote in marble. Those with the pretensions to worldly wisdom and political savvy can protest, but history's lessons are eloquent.

Now the redefined milestone of a "LUNAR RESOURCE STATION CAPABLE OF SELF-EXPANSION" is still just that, a milestone. Granted it is a better milestone because it pays greater respect for what ought to be our goal. We haven't mentioned that as yet.

We do need a goal in our space endeavors for the nation and for the National Space Society. The current incrementalism in official favor (in both cases) is a cruel hoax. It teases us forward with groundless hopes. Our goal cannot be mere exploration if it is to relate to pressing needs on Earth instead of competing with them. *Our goal, transcending any specific milestone, must be TO INTEGRATE SPACE RESOURCES WITH EARTH'S ECONOMY* for the betterment of the overwhelming majority of mankind who will continue to live here, lofty (L5) pipe dreams aside, for the foreseeable future.

The big silly debate these days continues to be "Moon Base versus Mars Exploration." But let's adopt instead the transcendental goal just proposed *without specifying milestones,* and everything will fall into its proper place, *a Lunar Resource Station being but the down-payment.* Steps to begin utilizing other space resources will follow, putting into place an economy of organic interdependence. Then all of us, or our offspring, will find ample room to realize our separate favorite dreams.

We have supported the Return to the Moon Petition currently being circulated, but only because it includes the hedging and issue-skirting phrase "and commercial endeavors." As a sentiment expressing national purpose, it suffers from the myopia of any milestone parading as a goal

What we need right now is *not a bigger and better milestone, but a transcendent goal that will exert an irresistible tidal force on all our efforts,* reshaping them where necessary. For this purpose, neither "Moon Base" nor "establishing communities beyond Earth" works. Granted, it is always easier to promote a concrete milestone. You can graph it, draw and color it, budget it, compare it. Yet no amount of effort can turn a milestone into a goal.

Fellow space advocates, anything worth doing is worth doing right! A little pain in realigning our sights now will save almost certain disappointment later. **PK**

HELIUM 3

by Eric Ryden, Chicago Space Frontier L5

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

The workshop assessed fusion energy methods and approaches for lunar surveying, mining, processing, storage, transportation, and facilities required for recovery.

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

Analysis of lunar regolith showed that higher titanium dioxide (TiO2) levels correspond to higher 3He levels, a relationship which could not be explained. Distribution of TiO2 might be made by remote sensing to infer 3He distribution, since 3He cannot be directly detected. [Ed. Higher titanium concentrations are found principally in some mare basalts. We may also want to map high-titanium basalt distribution in the maria to locate the best concentrations of ilmenite, an iron-titanium ore whose processing would produce liquid oxygen.]

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

Lunar oxygen production from ilmenite ($FeTiO_3$) after 2000 could demonstrate lunar mining and processing, as well as generating metals and small amounts of ^{3}He as byproducts. However, this process is not efficient for ^{3}He production because most helium would be lost in the concentration of $FeTiO_3$ from regolith. Alternatively, heating regolith for ^{3}He production also creates volatiles such as water, which could be utilized for other lunar activities. Thus the existence of either a lunar base or a ^{3}He production facility could affect the planning and development of the other.

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

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

COLONIST QUIZ: The Moon's Surface

Questions

[1] What evidence is there to the naked eye that the Moon's entire surface is covered with a fine dust layer on a centimeter (half-inch) scale at least?

[2] Were any exposed outcroppings of unfractured lunar bedrock spotted by the Apollo astronauts?

[3] Do we have any idea of the source of the meteorite material that has bombarded the Moon?

[4] What is the "regolith"? How uniform is it?

Answers

[1] The disk of the Full Moon appears to be of similar brightness edge to edge. If the surface was bare rock, the edges would be much darker.

[2] Lava flow outcroppings, both massive and thin-bed (less than 1 meter) were spotted in the west slope of Hadley Rille (Apollo 15 mission).

[3] All sites show a soil component (1.5-2% by weight) derived from meteorite bombardment with the volatile enriched element abundance characteristic of type 1 carbonaceous chondrites (C1). Signatures of other meteorite classes are rare.

[4] Regolith (we predict settlers will abbreviate this to 'lith) is a continuous debris layer which blankets the entire surface of the Moon from a few centimeters to several meters thickness, and ranging from very fine dust (the portion finer than 1 millimeter being called soil or fines) to rocks meters across. Below this are many meters of fractured bedrock, and finally solid bedrock. About 50% of the regolith at any site originates by impact debris from within 3 kilometers, 45% from 3-100 kilometers, 5% from 100-1000 kilometers, only a fraction of a percent beyond that. About 10-30% of any given maria soil sample is of highland type. Most of the fine pulverizing comes from on-the-spot micrometeorite bombardment, a very slow process taking some 10 million years to thoroughly 'garden' the upper first centimeter.

[See the article on Lunar Ores on pp. 8-9 above and the one on "Tailings" below.]

GAS-SCAVENGER

Waste-not, Want-not: Available Byproducts of Soil Moving

by Peter Kokh, based on these sources:

1 Lunar & Planetary Institute, Houston and Research School of Earth Sciences, Australian National Univ., Canberra. pp. 147-169.

2 "Water and Cheese from the Lunar Desert: Abundances and Accessibility of H, N, and C on the Moon" by Larry A. Haskin, Dept. of Earth and Planetary Sciences and McDonnell Center for the Space Sciences, Washington Univ., St. Louis, MO.

The powder-like dust of the lunar surface is a housekeeping scourge. But this same fine grain texture carries with it a fringe benefit that more than makes up for any nuisance factor. It was one of the biggest surprises of the Apollo Moon Rock studies to find that this pulverized soil had been acting like a sponge soaking up the solar wind for four thousand million years. While the lunar rocks and soils themselves are extremely dry and deficient in volatile elements (those which melt and vaporize at relatively low temperatures) there are plenty of these elements both adsorbed to fine grains and trapped in minute cavities and pockets within soil particles.

Particles from the solar wind, from solar flares, and from cosmic rays, each leave characteristic traces and from these it is clear that the solar wind has been the main source of the volatiles we now find. Other sources include volcanic fire-fountains or fumaroles and meteoritic or cometary bombardment[1]. By all these means, the upper meters of the lunar surface has become effectively saturated. A lunar form of fossil sunshine if you will.

Travelers in the Wind

Foremost of these guest elements is hydrogen - protons comprise 90% of the solar wind - followed by Helium - alpha particles comprising 10% of the solar wind1. While no hydrogen has yet been found in lunar rocks proper that gives any indication of being native and while no water or water-ice has yet been found [*as of 3/'89, eight years before the Lunar Prospector mission*], the amount of adsorbed hydrogen is far from negligible.

It is now estimated that there is enough hydrogen in one cubic meter of lunar topsoil to yield, combined with lunar oxygen more than a pint and a half of water.

Extending this figure to the Moon at large, the total global regolith layer, if it could be harvested 100% for hydrogen, could yield a lake of water 10 km wide x 68 km long by 100 meters deep (roughly 6x40 miles by 330 ft. deep).2 While this is hardly an ocean full it is a surprising amount all the same. The real question is whether this endowment can be harvested economically.

Carbon and nitrogen, which are found as traces in the rock (30 and 1 parts per million respectively) are enriched in the regolith soil to 115 and 82 ppm (kg per thousand metric tons).1 Another way of putting this is that an area mined 6m long x 6m wide and 1m deep contains as much nitrogen as an average human body. Or consider that the amount of carbon locked up in soil organisms on Earth is only 2.7 times the amount of carbon adsorbed to the same amount of moondust. It's just there in a totally different form than we are used to finding and harvesting it. We need new methods, new tools, a new way of living off the land.

In Earthside laboratories, gasses trapped in lunar soil samples have been released by simple heating. Some gasses will need more heating to scavenge, others less. Further pulverizing may be needed to release compressed gasses trapped in glass cavities and vugs (small, irregular-shaped, rough, crystal-walled cavities inside rocks) at pressures commonly as high as five thousand atmospheres! Laboratory methods are one thing. Engineering the equipment to do the job economically on a large scale in routine fashion is another. Here is a hardware R&D job as ultimately important as any.

While it may be true that extracting the H, C, and N in a finite amount of lunar soil could provide for all the needs of an appreciable biosphere2, the first milestone might well be the ability to make up for all leakage losses with the gasses extracted from the soil in the everyday 'lith-moving involved in building roads, excavating shelters, covering new habitats with shielding etc. As this would mean that all imported H, C, and N could go towards increasing the size of the bios-phere, it would be a major step on the road to self-reliance.

What we are suggesting then is that any piece of regolith-moving equipment involved in constructing the various parts of the base/settlement-to-be or providing the various processing plants with ores should routinely process all the soil it handles to harvest the gasses trapped in the soil.

This capability should be built-in. On page twelve of this issue, there is a sketch by Pat Rawlings (Eagle Engineering) of a mobile soil harvester in the service of the liquid oxygen industry. This sketch appears in Ben Bova's 1988 book Welcome to Moonbase. In our view, such a machine should never be built as depicted. Scavenging soil gasses (not including the oxygen chemically combined in soil minerals, at c. 45% by weight) must not be an afterthought, an accessory to be added later, a luxury to be built into future models.

Scavenging soil gasses will be an exercise in self-endowment and the settlement that does not practice it *de rigueur* will not deserve to succeed. Gasses harvested in excess of current need will become a capital investment in the settlement's future. A lunar community that practices such gas scavenging will have a friendlier more at-ease attitude to its adopted world than one which, not doing so, chooses by default to remain *a stranger in a strange land.*

It's hard to say what a proper gas scavenging soil mover would look like. A lot depends on whether or not it is practical to do at least a first sort of the different gasses into separate tanks on the spot, possibly attached to sequential heating chambers, or whether this task is best done in a fixed plant. If the gasses can be stored compressed, the soil mover can do more work before unloading full tanks and taking on empties. Is anyone working on such a gadgetmobile? We would be surprised.

The Noble Gases

As to the noble gasses (chemically inert, not reactive with other elements) each cubic meter of 'lith contains an average 20 grams of Helium, 2 each of Neon and Argon, 1 of Krypton, and a milligram of Xenon. The extent to which these gasses can be economically extracted from the soil may well determine which form of lighting bulbs and tubes it will be most feasible to manufacture on the Moon using the highest possible 'lunar content'.

Will neon lighting, presently undergoing a tremendous renaissance in this country, play a major role in illuminating as well as decorating lunar habitats? As soon as a settlement reaches a certain viable size it will pay for it to provide for its lighting needs by self-manufacture so this question is not an idle one.

The Implications

There are strong implications in all this for lunar city-planning. Contrary to the usual vision of lunar settlements in which personnel are limited to cramped quarters sardine-style, our future lunar sodbusters engaged in routine gas scavenging may find it profitable to construct more square footage of habitat and more footage of pressurized passages and roadways per person. As avoiding cabin fever will be harder than on Earth, this may be the only way to sustain general mental health and morale. Lower density living brings with it lessened vulnerability to impact damage, and a larger biosphere mass per inhabitant i.e. "MM Manifesto!" **MMM**

TAILINGS

Tailings from Mining Operations

by Peter Kokh

TAILINGS: (TAY'lings) the residue of any process such as mining. The leavings.

The Challenge and the Opportunity

Anybody who has ever visited a mining area, has seen the large talus slopes or mounds of pea to acorn sized rubble of unwanted material that nnounce the approaches to mine openings. This is the chewed up and spit out host material in which the desired ore vein was embedded and which had to be removed to get at the prize. Tailings also refer to the the accumulated leavings after the sought after metal is extracted from its ore. As a rule, the volume of tailings is enormously greater than that of the extracted ore. This is especially so with the noble metals, gold, silver, platinum, and copper. In the case of copper, for example, the volume of tailings to metal is typically 100:1.

To the environmentalist without imagination, tailings are a terrible eyesore. To the rare creative environmentalist and would-be entrepreneur, they are instead a vast untapped resource just begging to be put to work.

What is so special about tailings that would justify such a bold statement? Simply this: tailings have already undergone a considerable amount of work. They have already been extracted from the mine site, and are already uniformly ground up into bite-sized pieces often of quite uniform composition. As such they are already preprocessed and represent a substantial energy investment that goes utterly wasted when they are allowed to just sit there scarring the landscape.

In much of the world where rich ore veins exist, paradoxically there is often a scarcity of the traditional building materials. True friends of the Earth would quit wasting time ranting and raving about scenic eyesores and spend their time diligently experimenting with these tailings to see what sort of building materials they could be turned into, putting to advantage the energy investment that has already been made. Alas, creatively enterprising environmentalists are about as common as woolly mammoths.

Back on the Moon

On the Moon, we will find soils richer in this element, soils richer in that element, but likely only in degrees and percentages. While prospecting for especially rich deposits of strategic materials will have its ups and downs, probably more of the latter, basic needs will be able to be met by surface mining of the loose *topsoil* at almost any *coastal* site, as such areas have access to both the higher aluminum and calcium rich highland soils and the iron and titanium rich basaltic (lava flow) mare soils of the lunar 'seas'. Among coastal sites, those that also have KREEP (potassium, rare earth elements, phosphorus) deposits will have a special advantage.

The ore company, let's call it Ore Galore Inc. or OGI, will first separate the loose lunar soil or fines into fractions by electrostatic and/or mechanical means. These fractions will then go to various processing facilities dedicated to the production of oxygen, iron, aluminum, titanium, magnesium, glass and glass composites, lunar cement, etc. At the end of each processing line there will be leftover material, tailings. These tailings will often be as rich as the material that undergoes final processing, but will be discarded because they cannot be processed as easily or economically.

Now the principal lunar industries will be concerned with the two most urgent needs, export to pay the bills, and basic shelter: habitat construction. Frills, such as finishing materials, interior (i.e. secondary) building products, furnishings, etc., will have a much lower priority for OGI. The lunar entrepreneur, experimenting in free time if necessary, will have on hand any number of piles of tailings, each probably with some characteristic gross composition resulting from extraction of the different desired elements.

Tailings-based Building Materials
Reusing Spent Energy

The tailings at the Glax™ (glass-glass-composites) plant will differ from those of the Iron plant or the cement plant etc. We could just leave them there, but considerable energy will then be wasted, the energy which has gone into their sorting and prior scavenging for adsorbed gasses. But the real opportunity that suggests itself is to turn these tailings into various secondary building products meant for finishing and furnishing habitat interiors at the settlers' labor-intensive leisure. These can include decorative panels (glax), tiles for walls and floors, ceramic and glass home wares, special glax compositions for distinctive furniture etc. OGI cannot be bothered with sourcing for such needs but will be only to happy to provide tailings for the taking. Simple opportunism, neighborly and environmentally aware to boot.

Consider the tile-maker. The tailings from the glax plant, when melted and cast, may yield tiles of one characteristic color pattern (very likely variegated), while those from the iron plant may yield another. Aha! variety! interest! choice! - the stuff to whet consumer appetites by allowing personalization and customizing of habitat interiors at leisure once the cookie-cutter pressurized habitat shells have been appropriately mass-produced in the least possible labor-intensive manner. In these various tailing piles lie the seed of incipient lunar entrepreneurialism and small business free enterprise.

The environment-respecting aspect of such products might be advantageously marketed as such to the aware consumer. For example, tiles made from cast tailings might be called 'slaks' (from 'slag').

There will be an especially great demand for coloring agents -- on the Moon that will mean metal oxides exclusively rather than the complex organic dyes made from coal tars etc., that we are used to -- coloring agents for ceramic glazes, stained glass, and special inorganic *paints* (probably using waterglass, liquid sodium silicate, as a base*) etc. Some tailing piles may be richer sources of one such colorant or the other. Some sources may be prized for yielding products of special textures or other desirable properties.

When possible, reserving primary building materials for export products, tailings-based materials for domestic products.

On the one hand, because of the urgent priorities imposed by the need to justify the infant lunar settlement economically, basic end products such as iron, export quality glax, etc. could well be off limits to the home-improvement product manufacturer. On the other hand, using raw unprocessed regolith or soil may yield only a quickly boring and unvaried product line, and further disturb the surface. Pre-differentiated tailings offer a handy and elegant solution.

Test of Settlement Industrial Efficiency

There is perhaps no better single criterion by which to judge a society's environmental impact than *the degree to which its material culture uses resources in proportion to their availability.* On Earth, our record is abysmal, even amongst cultures which 'live off the land.' We still discard as unwanted too much material after investing precious energy to sort through it for some prized content. If tailings-based building products industries were pursued vigorously here on the home world, there would be far fewer shelterless people in the world, if any, and their homes could be more substantial and satisfying. All it takes is a few people with justified environmental concerns who are willing, to spend more effort in concrete solutions than in raising hell. Complaining is so cheap!

On the Moon, industries should be built up to utilize all the elements present in abundance: with oxygen, silicon, iron, aluminun, titanium, and magnesium, the eventual uses are obvious though requiring different degrees of sophistication. Calcium is the one very abundant element, especially in the highlands, that is most likely to go underutilized. Calcium, of course, is a major ingredient of cement, and Lunacrete, as investigators have begun to call it, is one of the most promising building materials for lunar installations, if and only if a cheap enough source of water, water-ice, or hydrogen can be located and accessed**. If not, the choices will be either to discard calcium with tailing piles being characteristically calcium-rich, or to accept the challenge of finding other ways to put it to use. Whitewash could be one of these.

A lunar administration granting licenses to enterprises might give tax or other incentives to those that are tailings based, to encourage opportunistic usage of material already extracted, rather than allowing additional square kilometers of lunar soil to be mined. This can be done simply by refusing license to mine or use unprocessed lunar soil to manufacture secondary products. Industries should be encouraged to form in a raw materials cascade in which one industry uses for its raw materials the discards of another, until the ultimate residue is minimal or nonexistent. Not only would such a material civilization have the highest standard of living at the lowest environmental impact, it would also use and reuse energy in the most efficient way. Combine this with recycling, and t*he ultimate test of a mature civilization is one without residue.* That is a stubborn goal, so hard to realize that it may seem economic fantasy to some, but one nonetheless worth insistently striving for. The rewards will be great. But above all, on a world where so little is handed to us on a silver platter, only such total use of what we do mine may allow us to beat the economic odds stacked against our success.

Next time you pass a tailing-scaped mining site on some Earthbound highway, stop and take another look. There are fortunes to be made in this unwanted stuff, and preparing for Moon-appropriate industrial protocols while filling vast unmet needs here below might not be such a bad idea. Now if I were still a young man! **MMM**

* [We subsequently actually experimented with such "paints", producing the first Lunar-style painting in September, 1994]

** [Dr. T. D. Lin has since performed successful experiments using steam instead of liquid water, reporting on this work at ISDC '98.]

Moon Miners' Manifesto #24 - April, 1989

"Space Resources for Earth Problems" A Banner-Worthy Goal

Commentary by Peter Kokh

Many of us space advocates are all too painfully aware that our own 'premature' birthdates and mortality conspire against our ever participating in the actual unfolding drama of the realization of a space frontier. Others are unwilling to admit such a possibility and have deep held hopes of personally blazing the trail. Whatever our personal expectations, most of us have found a particular niche on the would-be frontier in which we think we would be most at home. Speculating about such a niche gives us great vicarious pleasure and drives us on. Some of us would pioneer the Moon, others Mars, or the asteroids. Or perhaps we would wildcat dormant comets, or work on the construction of giant space colonies, or run a tourist hotel out by Saturn. Same of us may even dream of inventing an interstellar drive. Meanwhile we chafe at being exiles in time, born too soon.

And also meanwhile, we lie to others about our 'unusual' passion. For we learn too quickly that these visions, however viscerally exciting to us, leave most people cold, coming across as pathetically out of touch with reality, even cruelly indifferent to the world's many terribly urgent needs. We stand silently accused of a cruel and selfish escapism.

In response to expressed or latent hostility of those concerned with a litany of 'more urgent' problems, as well as in reaction to the apathy of those concerned with nothing beyond the gratifications of the moment, we've come up with various strategies. We talk about the many spin-offs of space technology, for example. Teflon hoopla is seen as the answer to those who ask 'what's in it for me?' While spin-off benefits are real, they are not the reason we are pushing the envelope of human horizons out into space. In offering spin-offs to the public as 'the reason' for space exploration and development, or as a palliative to help swallow the high capital costs involved, we are being dishonest, even cynically so, to the public and to our own dreams as well.

Some have tried to anchor the hopes of the space frontier on the persuasion value of fear. They see in the militarization of space, something upon which civilian access can be piggybacked. The S.S. Paranoia is their spaceship. This course is laden with pitfalls and the chances of it backfiring tragically, seem to this writer considerably greater than the Alice-in-Wonderland likelihood of success. Behind it all is the unspoken pessimism that if it were not for mutual hatred and fear of peoples of Earth, we could not hope to realize a spacefaring civilization.

Another growing fad is to use the darkside of humanity as a launchpad in a subtler, more sublimating way. Thus we are told we should go 'to Mars Together' as an arms-race substitute.

The rival option is to set up an Antarctic-style science base, and possibly a farside observatory, on the Moon. Proponents of this option cite the priceless value of science without the need to know in advance what improvements in life such enhancements of present knowledge might eventually bring. If both the SDI crowd and the Mars crowd pay too much homage to the worst of terrestrial crises, the Lunar science crowd goes to the other extreme and plays ostrich.

Why do we have to lie to the public about our motivations? Why do we have to keep our 'real agendas' hidden? The answer is that all too often we ourselves have no real grasp of The Goal but see only particular milestones with whose realization we can individually identify. Nor do we agree amongst ourselves for the same reason: we mistake these milestones for goals.

Let's stop this nonsense! The *only goal* we can be *honest* about with the public, and undefensively ballyhoo, is one which relates to the real *ENVIRONMENTAL-ECONOMIC problems of our home world.* Such a goal was first formulated by Gerard O'Neill in THE HIGH FRONTIER (before that phrase was usurped and twisted by the fright and might crowd). According to this vision, space resources would be put to work to furnish Earth's growing energy needs in a way much friendlier to the environment than coal, oil, fission, and even hydroelectric plants.

Getting Stuck on a Detail
Getting Back on Track

A funny thing happened on the way to the forum (where we tell the good news to the public). Too many became captivated by the vision of space colonies, one of the proposed components of the energy from space scheme, and mistook these future celestial oases as the goal. To these supporters, serving Earth's needs has been merely a handy means to that goal. In truth, it should be the other way around: space colonies fall under the heading of means, Earth's needs being the goal.

The O'Neill vision is one that needs to be ever refreshed, ever reformulated. Solar Power Satellites need to be rethought to see if they can be designed to be less obtrusive in the night skies of Earth. Nor should they be seen as the only possible means of realizing the goal. Lunar helium 3 [Eric Ryden's report in MMM # 23] is also a candidate. The future will probably see both. As attracted as we are to individual facets of the original High Frontier scheme, we must be honest enough with both ourselves and the public to reserve out highest loyalty to *THE goal* -- nothing short of rescuing Earth's environment with greater economic justice than possible in any other way.

This goal itself needs to be ever restated concretely, addressing the terrestrial crisis in the most relevant way. For example, today's buzzword is the Greenhouse Effect, a very real concern (though some say we should be sure it is upon us before we rashly do anything to prevent it!). Power from space is the one viable alternative we have to continuing to warm the Earth by power generation on the surface. It is also quite possible that power and resources from space (and some technologies developed in anticipation, e.g. glass-glass-composites or Glax*) can slowly reduce the rate at which our tropical forests are being clear-cut, causing irrevocable gross mass extinctions.

Many environmentalists are highly stirred up about the rape of the planet but have yet to grasp that until a changed regime governs the microeconomic decisions made by individuals and families, the juggernaut of habitat (and Habitat Earth, with a big H) destruction will continue. Only space resources offer an alternative.

Some critics see space resources as a *deus-ex-machina* (god out of a machine), an improper recourse. But space *IS* an integral horizon of our planet, it *is* our "hinterland". The Solar System *IS* Greater Earth. Not to use it would be perverse. ***SPACE IS AN EARTH RESOURCE*** - let that be our cry. Let us work to show the many ways space development can address the mundane problems all thinking people are concerned with. Space is not pie in the sky. It is future bread on the table. Space is not a luxury. Space is a necessity if we are to survive the adolescence of our species.

Integrating space resources into Earth's economy in a way beneficial to all her inhabitants is not a vision we have to keep close to the breast, that we have to be shy about, that we have to serve by offering substitute sops to the public. It is a goal we can shout about from the roof tops. Being in the service of such a goal is a badge we can wear with pride. Only ignorance, ours included, stands in the way.

Dedicate ourselves to this goal and all our individual private fantasies will see the light of day, science camps, resource stations, and eventually settlements on the Moon; permanent human presence on Mars; self-contained colonies in free space; asteroid mining; and much, much more. Instead of being divided by such words as Moon, Mars and Space Colonies, space advocates should be united by the word EARTH. As far as we go in space, even if it is to the stars, we will never find any adopted home as beautiful, as fertile, as rich as Earth. Working to keep it that way should be our reason for g. That is the only thing deserving the term GOAL. - **PK**

AsTERoid$

Introduction to this Asteroid theme issue
by Peter Kokh

There’s a lot to say about asteroids and we won’t be able to cover it all in one issue. But we hope to give you som insights you’ll find nowhere else. Much attention is now given to Earth-approaching asteroids easier to reach than those in the Main Belt , we will point out some interesting possibilities for the Belt’s “Big Three” that others seem to have missed.

We’ll have only space to hint at the many fascinating cultural & social aspects of some future “Belter” civilization, but that will give us excuse to do a future follow-up issue.

Two Pesky Questions for Debate

(1) Will Earth citizens’ fears, justified or not, of possible collisions with asteroid “bergs” being brought back by mass driver, lead to herding them to one of the Earth-Sun Lagrange points instead of near-Earth orbits? If so, a whole complex of space colonies might be located out there, processing the incoming ores into manufactured goods for shipment to Earth and Moon.

(2) Will environmental concerns about using mass drivers for propulsion lead to requiring them to maintain a debris stream exit velocity sufficient to escape the solar system least their orbiting clouds of exhaust *shot* add to space travel hazards?

Colonist's I.Q. Quiz on Asteroids

Questions

[1] True or False. The asteroids are all that remains of a lost planet that once circled the Sun between the orbits of Mars and Jupiter, and which disintegrated in some unknown catastrophe.

[2] True or False. The Asteroid Belt is thin like Saturn's rings.

[3] True or False. The main portion of the Asteroid Belt is so thick that from the surface of any one asteroid, many others should be visible to the naked eye.

[4] True or False. All asteroids are irregular in shape much like little Phobos and Deimos, the tiny moons of Mars, themselves possibly former asteroids.

[5] True or False. There is a correlation between the types of meteorites we have found an Earth and the various classes of asteroids.

[6] The asteroids being so small and far away, how is it possible that we know anything about them at all beyond their orbital statistics?

[7] Are any asteroids important enough in their own right to be more than chance targets of opportunity?

[8] How many asteroids have so far been discovered in "Earth-Trojan" orbits, preceding / following Earth in its orbit in the stable L4 / L5 Earth-Sun Lagrange points?

Answers

[1] The theme of several science fiction stories, this is one of those romantic notions (much like that of Atlantis) that dies hard. The overwhelming evidence and the mainstream opinion is that no single planet was able to form at this distance from the Sun because of the disruptive effects of Jupiter's gravity, evident today in the several gaps (e.g. Kirkwood gap) or zones of avoidance in the belt where the orbital period would not be a simple harmonic of Jupiter's.

The total mass of the known (about 4,000) AND conjectured asteroids together is much less than that of the Moon, which would have made for a small planet indeed. While most people now reject the “Lost Planet theory”, many still cling inadvertently to another theory that stands or falls with it, namely that before the hypothetical Lost Planet broke up, it had become differentiated with heavy metals towards the core, stone and water to the outside, and that same fragments must be incredibly rich pure metal as a result. Instead it seems certain that denser, stonier asteroids formed nearer the Sun, water-rich carbonaceous ones further from the Sun. The original family of asteroids has probably all been broken up and reassembled by mutual impacts in the 4 billion years since formation. But it is unlikely that any of the original number, Proto-Vesta being the sole possible exception, was ever large enough or hot enough to undergo differentiation.

[2] False. The range of orbital inclinations to the mean plane (represented by the Earth-chauvinistic ecliptic or much better by Jupiter's orbital plane) is quite high, averaging about 10 degrees with some stragglers inclined as much as 43 degrees (#944 Hidalgo). The greater the inclination of an orbit, the harder (more delta V) it will be to reach from Earth.

[3] False. The image of a packed belt may set a mean stage for science fiction stories and movies, but the “Belt” is mostly empty space. Take a thickness of 100-200 million miles, a depth about the same, and a circumference on the order of 600-1000 million miles and sprinkle with a few thousand asteroids and they will all be pretty lonely. Occasionally asteroids will pass one another close enough to be seen with the naked eye. But Earth, Mars, Jupiter, and Saturn will thoroughly dominate asteroid skies.

[4] In theory, any body of 250 miles diameter or more will have sufficient mass to shape itself 'in time' into a body with an equipotential surface: a sphere. The evidence from Voyager views of the small moons of Saturn fits this well (Hyperion clearly suffered from a geologically recent major impact, and is the exception). In fact, Ceres, by far the largest, may be the only asteroid that fits this spherical mold.

[5] True. The spectral analysis of light from various asteroids seems to coordinate very closely with meteorite classes, signifying that the Belt is their source.

[6] As we have just indicated, the asteroid's light can be passed through a spectrograph which, acting like a prism breaks up the light into its component colors, gives a clue to the surface composition. Photometric studies of light fluctuations can tell us about a body' s rotation rate and even its polar inclination. Polariza-

tion and albedo light reflectance studies can tell us more about composition and granulation. Only a few asteroids have been thoroughly studied in this way, a neglected field crying for amateur attention. Only one, Vesta, has been crudely mapped by the new process of speckle interferometry.

[7] Vesta seems far and away the most interesting for several reasons. Ceres, the largest, and Pallas to a lesser degree, are inviting targets - see the articles that follow. The rest all fall into well-known classes any of whose members will probably yield as much information as any other. All the asteroids so far mentioned for flyby encounters on the road to Jupiter are targets of opportunity, no more.

[8] Despite careful searches that should have turned up anything larger than a couple of kilometers across, no such Earth coorbital bodies have yet been detected. As such bodies would provide continuous travel opportunities at very low delta-V, this is rather disappointing.

(1) CERES ⚳

DIAMETER: 1003 kilometers or 621 miles.

SURFACE AREA: 3,160,000 km2 (1,219,000 mi2)

COMPARISONS: slightly larger than either of:

- all the U.S. east of the plains states (i.e. not incl.
- Dakotas thru Texas)
- all the U.S. west of the plains states
- Queensland plus Northern Territory (in Australia)
- All the Moon's nearside seas together except the Ocean of Storms, O. Procellarum

CLASS AND COMPOSITION: Carbonaceous chondrite. Stony (silicates and metal oxides) with admixed ice and hydrates.

ROTATION PERIOD (one sol): 9.08 hrs.

POSSIBLE RATIONALIZATION: A two date cycle of 5 periods would yield dates of 22 hrs 42 min. A three date cycle of 8 periods would yield 24 hrs 12.8 min.

GRAVITY: 19% Moon's, 8.31% Mars', 3% Earth's.

DISTANCE FROM SUN: 381-447 million km = 237-278 million mi. = 2.55-2.99 A.U. [1 A.U. or astronomical unit = the Earth's average distance from the Sun

COMPARISONS: Ceres averages 2.77 times the Earth/Moan distance from the Sun. To collect the same amount of solar energy as a 1 meter diameter collector on the Moon (or a 1.512 meter collector on Mars), a collector on Ceres would have to be 2.77 meters in diameter (7.67 x the area).

Ceres was the first asteroid to be discovered and is by far the largest and may contain as much as one third of the total asteroidal mass. As you can see from the 'illustrated' statistics above, Ceres may be a small body in comparison with Earth and even the Moon, but it is quite a big little world all the same. In diameter Ceres compares to the Moon (1:3.48) as the Moon to Earth (1:3.67). What would it be like to live on Ceres? All the clues lie in the data above.

Outposts on Ceres

Ceres' gravity, the largest in the Belt at 33 cm/sec2, may yet be too low for human physiology to adjust to without degrading to a level most might consider unacceptable. All the same, it is a sure bet that some humans will ignore the recommendations and make that adjustment for better or for worse.

Those not wishing to put human adaptability to the test, could have any level of gravity they desired, Lunar, Martian, or Terrestrial, if they lived in a rotating habitat. This could be achieved in three basic ways:

- a rotating space habitat in orbit about Ceres -- synchronous orbit would be 486 mi. or 782 km above Ceres' equator -- elevator anyone?
- on the surface riding a properly banked and sized mag-lev rail or Gravittrack™
- on the surface and suspended in pairs or otherwise counterbalanced from a rotating pole like an amusement park ride or Maypole.

Each of these would require radiation shielding. The second option would be the easiest to shield, the third possibly the cheapest to build. It is likely *Ceresians (Cerians?, Cerealians?)* would spend part of their day on the low-grav surface, the rest in the higher-grav habitat. What works for Lunar architecture will not work on

Ceres. On the Moon (and Mars), internal habitat air pressure can be counterbalanced, at least in part, by the overburden of shielding soil.

In Ceres' low gravity, it would take five to six times as much shielding mass as on the Moon to achieve the same stress relief. So habitats on Ceres must be built as if they are spaceships or surface vehicles, probably cylindrical or spherical. Secondly, the soil on Ceres may be in a permafrost condition. It would then be necessary to excavate a larger trough and backfill with dry rock to prevent the heat-radiating habitat from slowly settling deeper into the soil.

What purpose could an outpost on Ceres serve? The asteroid itself probably has enough of everything (clay-like hydrate silicates, some metals, water-ice, carbon rich compounds etc.) to supply its essential needs but is unlikely to have export-grade mineral wealth. Rather, such an outpost would serve as a regional outfitting, resupply, maintenance, and service center (including hospital, educational, judicial, cultural etc.) for mining ventures to more richly endowed asteroid bits within easy delta-V range.

Ceres' "{Service Area"

If the stats for the first 100 asteroids to be discovered are typical,

> *44% have orbital periods within 10% of Ceres' so that one third of these or almost 15% of all asteroids would be within 60 degrees of Ceres at any given time and remain there for fifteen years or longer before drifting out of range.*

Some asteroids will 'fly in formation' with Ceres for centuries. Two target groups suggest themselves: the 'out-fronts' ahead of Ceres but in slower larger orbits, and the 'in-backs' behind Ceres but in faster smaller orbits. At any rate access to 15% of the Belt should do us well for quite a while. To compliment Ceres as regional centers, 210 km wide *#88 Thisbe* (takes 1415 yrs to drift 120 degrees with respect to Ceres) and 163 km wide *#39 Laetitia* (3540 yrs to drift 120 degrees) might serve well.

Facilities on Ceres

In time, engineering development for belt needed equipment (prospector ships and tools, mining equipment, mass drivers, smelting equipment) could switch from the Moon to this regional center. Experience gained on this colder, wetter world could prove useful for ventures beyond the Belt.

A short pool of names from which features and installations might be named. PIAZZI discovered Ceres in PALERMO, Sicily on the first day of CENTURY NINETEEN. Ceres was the Roman goddess of grain, and she chose the mortal TRIPTOLEMUS to carry her knowledge (the plow, agriculture) to humanity. The AMBARVAILIA were rites of spring celebrated by Roman farmers in Ceres' honor. Of course, miners will also bring with them more whimsical names e.g. The King Solomon's Mines Hotel (a real rat trap!)

(2) PALLAS

The Basics

With an average diameter of 608 km or 378 miles, Pallas, the second asteroid to be discovered, is a smaller world than Ceres. It's surface area compares with Mare Imbrium plus Serenitatis; or with Washington plus Oregon, California, and Nevada; or with New South Wales, plus Victoria, and Tasmania. Still enough land in which to get thoroughly lost.

Pallas is classified as 'peculiar chondrite' and from its radar signature appears to be rather smooth.

While its orbit is much more elliptical (bringing it about 66 million km or 41 million miles closer to the Sun than Ceres and taking it the same distance further out), its mean distance from the Sun is almost exactly the same as Ceres'. There are reports that Pallas has a 90 km satellite orbiting some 300 km above the surface. If confirmed*, this could be quite an asset especially if the composition of this unnamed body is complementary. [Observations since have ruled out such a large satellite.]

Pallas has a 10 hour hour day-night cycle. Pioneers would experience a dozen of its days to every five of ours.

Pallas is a "World Apart"

But the most significant statistic about Minor Planet #2 is its 35° orbital inclination to the ecliptic. We'd like to suggest that Pallas' relatively smooth surface is due to less total exposure to micrometeorite bombardment owing to this high orbital inclination. Seven other asteroids have orbits with a family resemblance but only a few very small ones have orbits more steeply inclined.

Pallas would thus be considerably harder to reach, requiring extra delta V. This could make it a mecca for pilgrim-type settlers wanting a world as off-the-beaten-path as possible, isolated and insulated from the cultural, religious, social, or economic ways of the rest of the Solar System. As influx of fresh blood will be inhibited, they might want to start with as diversified a gene pool as possible. Palladians [an adjective coined by the Romans] might trade knowledge and information gathered in their monastic isolation, via radio for essential imports by drone rocket. This world is very poorly placed to be a regional outfitting, supply, and service center.

Yet precisely because of this high inclination, Pallas offers *easily the best observatory platform in the Solar System for studies of the Sun's north and south polar regions*, when it is either high above or deep below the ecliptic on opposite legs of its 4.6 year long orbit. And this could be reason enough for establishing an outpost there.

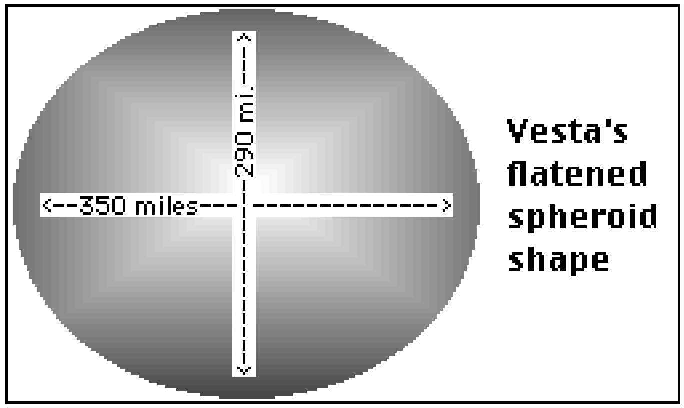
Pallas and Ceres

It takes Ceres almost 3000 years to lap Pallas - an extreme example of the disadvantage of orbital proximity. This century they are about 60 degrees apart (about 270 million miles) but as seen from Ceres, Pallas swings alternately nearly 100 million miles above and below its mean position. Travel in between is unlikely.

Name pool: Number 2 in order of discovery, Pallas was found by Wilhelm OLBERS, in BREMEN. The PALLADIUM was a famous statue of Pallas (Minerva).Names that suggest out of the way hard to reach places.

4 VESTA

Recent speckle interferometry studies of Vesta, Minor Planet #4 in order of discovery and the brightest as seen from Earth, have revealed a wealth of new information. A crude map of the surface has been constructed from the data which shows that Vesta is not quite spherical but more like a 'flattened watermelon' 564 x 531 km (350 x 330 mi.) in diameter along its equator by 467 km (290 mi.) along its polar axis.



Vesta rotates about its axis in a mere 5 hrs 20.5 min. A two date cycle of nine such periods gives dates 24 hrs 2.2 min long.Pioneers might organize their schedules accordingly.

Unlike either Ceres or Pallas, both dark bodies, Vesta's surface is relatively bright making it the only asteroid that is ever visible to the naked eye on Earth (but only in dark country skies!)

Vesta's surface composition

Spectral studies seem to indicate a basaltic, drier stony (eucritic) composition, not unlike the Moon (which, however, is much less reflective). The surprising presence of basalt indicates that at some time in its past, Vesta's interior had melted. A radioactive isotope of Aluminum seems to be the only likely source of the heat required in a body so small and would have done its work swiftly making any lava flow seas on Vesta hundreds of millions of years older than the Moon's. Some think Vesta may be the parent body of most stony meteorites.

A dry basaltic surface has both advantages and disadvantages. Some Lunar type construction methods might be appropriate. But it is possible that an outpost there would need to import some volatiles. Vesta's gravity might be not much less than Ceres' given its probable higher density. Its surface could include Moon-like lava filled basins and cratered highlands. Both surface sampling and orbital mapping are top priorities. A French probe to piggyback on a 1994 Soviet Mars mission is under study. [Ed. This *Vesta* mission never flew.]

The "Florida" of the Belt?

Vesta is also considerably closer to the Sun than Ceres or Pallas, ranging from 322 - 383 million km (200 - 238 million mi.) making the circuit in a year less time (3.63 yrs). One can imagine that *Ceres-Vesta oppositions every seventeen years one month apart may someday be the occasion of much ado in the Belt*, commercial, social, and what have you.

Tourist hype might refer to Vesta as the 'Florida' of the Belt. Yet it receives 2.4 times less solar energy per unit of surface area as does Mars (and 5.5 times less than Earth/Moon).

If volatiles are not a problem, Vesta may well be a regional outpost, quite possibly before Ceres itself. Except for the drier soil, the construction game plan will be similar.

Vesta as a Mecca for Physicists?

But Vesta could be most preeminent as a mecca for Physics. While it was once apparently molten, it is too small to have retained any heat. Add to this its probably dehydrated state, and it may be *the only body of size in our system in which it is possible to bore a shaft clear to center.* Imagine a large room with *negative zero gravity* (equal canceling pulls in all directions) shielded by 150 some miles of rock in all directions. That should be good for something! Such conditions could not be equaled nowhere else in the System. Given such an asset, an Vesta outpost or settlement might someday include a major university or institute.

Physics Homework

Here is some physics homework for someone: a 10 meter wide shaft to the core would involve removing about 75 million metric tons of material. How fast would this much matter have to be ejected in pulverized form out the end of a mass driver, *easterly* along Vesta's equator to slow significantly Vesta's swift rotation?

A terraformer's dream perhaps, but if Vesta's rotation could be slowed to once per orbit (sun-locked) a sizable 'sub-solar' region would then receive as much total sunshine as any spot on Mars, or about three times as much as presently. As a bonus, Vesta's 'farside' would then be the coldest spot in the solar system.

A short pool of names for features and installations on Vesta:

OLBERS discovered it in 1807 from BREMEN; Vesta was the Roman goddess of the HEARTH (home, warmth) sugggesting words for "hearth" in other languages. VESTALIA were ceremonies in her honor by the vestal virgins.

ASTROBITS

How will Prospectors Stake an Asteroid Claim? They will radio all the identifying information to some central claims office, of course; but perhaps they will want to put an actual marker on the particular orbiting berg they've prospected. A convention of some sorts would be needed to standardize procedure. One possibility would be to put a strobe beacon or radio beeper on the body's north (or south) pole. A hitch here is that, as we discovered with Halley's Comet, a small body can have two axes of rotation at once. In such cases the shortest axis or the one with the shortest period could be picked. Is there a better way to say “keep out!”? Suggestions welcome.

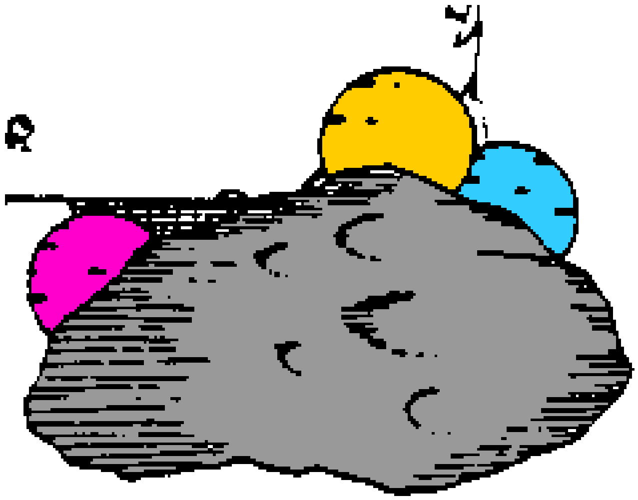
A Capital for the Belt? It is a tossup whether Belt communities would ever choose to federate or even loosely associate and need a "Capital City". If so, there is no logical spot within the Belt, Ceres' and Vesta's bids to the contrary, that will be easily accessible from anywhere.

The Moon offers much more frequent and regular Launch windows than any asteroid and will be a major, if not the major, source of supplies. That's if Belters can stand its (to them) crushing gravity.

Phobos and Deimos might offer space for such a headquarters, though *with much less frequent launch windows.* If Belters insist on an asteroid site headquarters, however, oddly shaped 36 x 15 km (22.3 x 9.3 mi.) *Eros* would be the best of a poor set of choices, offering reasonable launch window frequencies to most of the Belt yet accessible with perhaps politically desirable difficulty from both Earth and Mars. Of the other Earth-approaching asteroids, 35 km Ganymed is easily the largest but it has a very eccentric, highly inclined orbit with an unsuitably long period.

This would be the third 'Oscar' for Eros. When the asteroid (#433) was discovered in 1898, it became instantly famous as the first known minor planet to come within the orbit of Mars. Later, as its cigar-shape was deduced from its light curve, Eros inspired some to foresee the possibility of hollowing out suitably shaped asteroids and spinning them up to provide artificial gravity on the new inside surfaces and serve as great space colonies or even as star-bound arks, inspiring many (such as this writer) long before the days of Gerard O'Neill. **MMM**

Moon Miners' Manifesto
#25 - May, 1989



Asteroid Odds & Ends

by Peter Kokh

PALLAS & AN ASTROLOGICAL SCHISM

Potential settlers with a (mental) weakness for astrology and an aptitude for creativity, will have an opportunity for a fresh start. With Pallas' high orbital inclination, 35.85 degrees to our own orbital plane about the sun, ITS ZODIAC (the circle of constellations through which the Sun appears to travel) will be quite different from our own, having only two "houses" in common, where Pallas' orbit crosses the plane of our own, on the downswing in Pisces and on the upswing in Virgo. Palladians' unique set of "signs" would also include Serpens, Ophiuchus, Aquila, either Equuleus or Delphinus, Pegasus, Cetus, Eridanus, Lepus, Canis Major, Hydra, and Sextans -- ten great beginnings for a whole new round of sheer nonsense.

CERES (and the Belt in general)

At opposition, Jupiter will be as beacon-bright in Ceres' sky as Venus ever gets in our own. It may then be possible to pick out Jupiter's four great moons, Io, Europa, Canymede, and Callisto with the naked eye, the latter two being easiest to spot.

PODOKINETICS (FOOT POWER SYSTEMS)

Future Belters and others electing to make it the best they can without artificial gravity could do well with residual legs, there being little use for then, UNLESS, they adopted (as a "Protestant Work Ethic" sort of thing) the stricture that electric power for all luxury devices (personal entertainment and personal comfort etc.) be derived from pedal operated generators (possibly with power assist where the output, however well intended, would be insufficient, e.g. hot instead of cold shower water). If the VCR, the compact disk player, the vibrator, the cookie jar lock, the telephone, etc. would not work or open without pedaling, most would pay the price gladly. This would not work well unless it was a community-wide decision and we can foresee arguments as to whose turn it is to pedal up the communal holovision! Podokinetics would not maintain the body in Earth-normal tone by any means, but it could offer a badly needed physiological boost.

Podokinetic devices should be developed now, as a health fad device, so they are ready when gravity-less construction shacks are set up in space.

All the same, the residual legs of human dwarfs would be no handicap at all. Bare feet may be normal in many living and working conditions; and anyone with even remotely prehensile feet would be at a definite competitive advantage. Our final comment on being footloose among the asteroids - in the very light gravity these worlds offer, pogostick races may be THE outdoor sport.

TOWARDS EZ-GRAV

For those unwilling to accept the consequences of sustained life at minimal or no gravity, the easiest way to provide artificial gravity in space itself is not with rotating toruses, spheres, or cylinders, but with the tether. If all Belter ships were designed in polarized manned vs. tended sections (facilities whose automated systems needed to be tended only intermittently, minimizing transit from the one section to the other) the two sections, when not united for acceleration or deceleration boosts, could be easily split by tether to revolve around their common center of gravity. (see MMM # 21 Lunar Overflight Tours). Such 'binary' ships should be on the drawing boards now. Of course, that tether had better be strong and fail safe!

GRAVITY BY TETHERED ANCHORS

The combination of low gravity and typically fast asteroid rotation allows anchoring to an asteroid and paying out a tether beyond synchronous orbit distance to a point where the tether would whip the ship, station, or colony around the asteroid in step with the latter's rotation and provide through constant change in angular momentum whatever artificial centrifugal gravity one desired, "down" then becoming away from the asteroid.

As the required radius would be many hundreds to some thousands of miles in length, the spin-dizziness which will affect some persons on conventional space colonies would never arise. Such stations would be quite flat-floored, without the tight curvatures previously associated with artificial gravity.

Tethers of the necessary strength should be available by the time needed. A simple tether following cage would provide transit to the asteroid "up" below. A massive flywheel in the plane of orbit probably doubling as an energy storage device would keep the colony of station from twisting on the end of the tether. Docking could be at the asteroid-synchronous mark along the tether, between asteroid and station. This would also be the logical point for a surface to station elevator to swith orientation from floor-towards-asteroid to floor-towards-station. Outside excursions would be risky -- loose your grip and go on a real crack-the-whip fling!

Where Will the Belt Wealth Go?

Given that most people going out to the Belt will be making an all but irrevocable commitment to a permanent life at low-G, mininal-G, or no gravity at all, the dream that lures them outward will not be to go to the Belt to make a fortune, then come back to Earth (or the Moon or Mars) to spend it. The spending will be out there. Mineral wealth sent on its way to markets in the inner solar system will pay for imports of consumer goods out to Belt distribution centers. These can be either fixed (e.g. on Ceres, Vesta, etc.) or roving "gypsy general stores" that make the rounds between mining stations on prearranged itineraries. Of course we can expect specially configured minimal-G gin and sin traps set up in orbit around the major planets to snare some of those earnings before the suckers head for home.

LAVA TUBES

by Peter Kokh

In the event that the citizen-funded* Lunar Prospector 1 finds no indications of ice deposits in permanently shaded (*perma-shade*) craters near the Moon's north or south poles, there will still be some debatable pluses for siting a base near one of the lunar poles along with a litany of disadvantages. What then?

On many occasions, we have stated that a mare/highland "coastal" site makes the most sense because it allows access to both major soil types on the Moon, important if we want to make intelligent use of lunar resources. Such coastal sites frequently come endowed with topographical features of enormous potential advantage: lava tubes and sinuous rilles. Indeed, the most important site advantage for a base designed with settlement expansion potential uppermost, will be *close proximity to accessible lava tubes.*

Our evidence for lava tubes on the Moon is threefold, and though indirect, quite strong. The first evidence is the existence in many mare areas of sinuous rilles or valley channels such as Hadley which was investigated by the Apollo 15 mission. These are typically hundreds of meters across and deep and can be a hundred or more kilometers in length. Our best explanation for these features, one now generally accepted, is that they represent collapsed lava tubes. (Rilles bear none of the water-flow signatures so marked in Martian valleys).

The second evidence is the existence of chains (catennae) of rimless craters, often oval in shape, in several mare areas. Our best explanation for them is that they are collapse pits following along the top of a lava tube whose ceiling is within 40 meters of the surface, and with intervening stretches still intact. Finally, we find at least one "interrupted" rille, Hyginus, in which the interruptions appear to be intact lavatube sections, "bridging" the rille here and there.

There are many terrestrial examples of lava tubes, admittedly on a far smaller size scale (the considerably higher gravity on Earth being the determinant here) for example in the lava flow sheets covering much of Oregon and wherever the lava upwelling has had an especially low viscosity such as the Panhoehoe flows that have built up Mauna Loa/Mauna Kea (the Island of Hawaii). Lava tubes on Earth are typically 10-40 meters wide and high and may run several kilometers in length, and as a rule with a very gentle gradient. Their floors are sometimes flat (often with mid-floor channels handy for utility emplacement), sometimes strewn with rubble from ceiling spallation. We are only beginning to realize the extent of the honeycomb network of such tubes on the Big Island.

Our evidence that the lunar maria were formed by very low viscosity lava flows is substantial, and based both on compositional analysis of the mare basalt samples returned and the topography of the very flat flows themselves. Relatively high titanium content may be a factor in this fluidity.

While all those tubes of which we currently have evidence lie near the surface, it is totally groundless to conclude, as most writers seem to have done (we know of no exceptions), that this is the extent of their domain. On the contrary the morphological evidence is quite conclusive that the various mare areas have been built up by a succession of flows, each typically hundreds of meters thick.

Total mare fill thickness can be deduced from the size of subsequent crater impacts that have 'bottomed out.' In the case, for example, of western Mare Crisium (Pierce, Piccard) this thickness must be two km. or more. Another indication is the size and extent of ghost rim craters on the mare (e.g. Yerkes in western Crisium, Prinz on the Mare Imbrium/Oceanus border). Thus Mare Smythii which contains many such features, must be comparatively shallow.

Lava tubes in all probability radiate out from the source(s) of lava upwellings in one successive sheet above the other. Accordingly, some, subsequently filled or not, must lie quite deep and present a considerable challenge for detection and an invaluable especially pristine resource if found.

Some writers have suggested emplacing lunar bases within lava tubes. While it will be some time before we can afford to seal and pressurize even the smallest of these voluminous features, there are less ambitious ways to make use of them for initial bases or settlements. The Society's Oregon chapter has taken the lead in illustrating the very real advantages of near-surface intact tubes both for original siting and for subsequent base/settlement expansion, going so far as to carry out dry-run exercises with area Young Astronauts in suitable (but much smaller scale) lava tubes in the Bend, Oregon area east of the Cascades.

Lava tubes provide constant temperature volumes (about -4° F, -20° C) free from the hazards of micrometeorite bombardment, cosmic rays, ultraviolet radiation and solar flares (allowing lightweight inexpensive 'pressure suits') and thus ideal for warehousing and volatile storage (water-ice and gasses), expansive garaging space, and siting automated or teleoperated manufacturing facilities and laboratories that do not need, or even work best without, pressurization. Lightweight inflatable structures, perhaps of Kevlar, that do not need their own shielding overburden can provide whatever pressurized control centers or habitat spaces that are needed.

Access can be by a shaft through the ‘roof’ for freight and personnel elevators, utility conduits, even entry for sunshine concentrated and funneled by heliostats on the surface. It is, moreover, hard to conceive of a safer and more secure environment in which to emplace a nuclear power facility than an isolated section of lava tube.

As these features have already lasted 3.5 to 4 billion years (limestone caves on Earth are likely to last a few million years at best), and will outlast all existent terrestrial features without exception, a lunar lava tube might well be recommended someday as the best site in the entire Solar System to house some future grand archives and museum of all humanity. By the same reasoning, if you will pardon a little fun speculation, there would have been no better site in all the Solar System for ancient visitors from elsewhere who happened to have arrived millions, even hundreds of millions of years prematurely (from our point of view) to have left a calling card of sorts that would survive for as long as need be to be found by some as then barely conceivable native intelligent species (us). As such, lunar lavatubes have been aptly dubbed "attractors of alien artifacts."

Given the way they were formed, lava tubes may provide the best hunting grounds for future lunar gem collectors. At any rate, there is a future for lunar spelunking, although it will be quite a bit different from limestone cave exploration in karst regions on Earth.

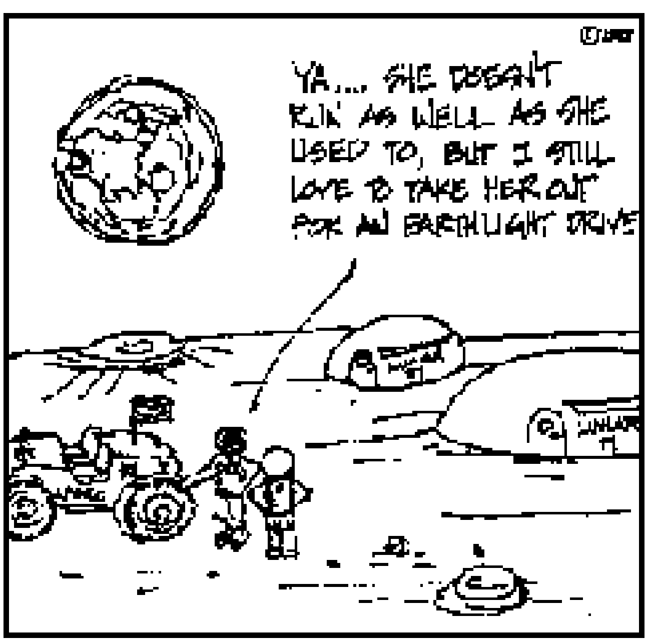
The cost of providing access to an intact lava tube pales in comparison with the cost of providing comparable volume by any other method of base construction. So while at least the first residential and agricultural areas will likely be excavated or built in covered trenches, Lunar Industrial Centers built in convenient lava tubes will have an enormous advantage over those that are not.

Our recommendation:

The National Space Society should consider raising funds for further studies of the existing photographic records for evidence of near surface lava tubes. Research into the best non-photographic methods of ferreting out such features from orbit also should have very high priority and if task-appropriate instrumentation can be devised, strong advocacy of a so-equipped follow-up probe in the Lunar Prospector series is in order.

* [When Lunar Prospector finally flew, some eight years after this was written, it was NASA who picked up the tap. Lunar Prospector was the 2nd outside mission to be picked up by NASA as part of its *Discovery Mission Opportunity* program. All attempts at private funding had failed.]

HARVEST MOON by Andy Weber



Asimov's Prediction

by Andy Weber

At the annual convention of the American Institute of Architects in 1988, the keynote speaker was Dr. Isaac Asimov. He had come to talk to the nation's architects about something that was on his mind and, in general, they weren't all too sure what they could expect from him. Many of them knew him and had red his works of science fiction, but if they were like me, they couldn't quite fathom just what he might have to discuss with architects. Nonetheless, we weren't worried because we knew that whatever it was he talked about, he'd present it in an entertaining way.

His presence alone was enough for me. There he stood with those huge gray sideburns that I'd seen before in photos, glasses with thick dark frames and his choice of clothes only semi-formal. His voice was deep[and rough and he never hesitated for a second as he prophesied. The "speech" that he gave was ll stored in his head and he needed no notes to guide his thoughts.

As it turned out, he wanted to speak about his theory and belief that

mankind should start to
move underground and live.

He felt that if we would *stop wasting all the precious topsoil* of our land and build underground there would follow many advantages and logical outcomes that would make life better for all. There would be technical problems for sure, but man had leapt technical hurdles far taller than any faced in moving some earth and burrowing in.

It sounded like Isaac should be one of the people who plan the first settlement on the Moon. That would make sense for many reasons, but the point is that too few people have actually thought through what it will be like psychologically to build and live on the Moon. On the Moon, the technical hurdles are a bit taller than the ones that go with digging homes out from under Kansas farm land, but certainly not insurmountable.

The psychological deterrents that Dr. Asimov cited as being the roadblocks to people living underground on Earth are the same as for Moon dwellers. Being beneath the ground is associated with death, graves, being buried alive, musty damp holes, hell, and all manner of other horrifying images. Those who first decide to live underground, just as potential Moon settlers, must be able to put all of these connotations aside and accept that wind in the hair and grass underfoot are going to be sensations left behind. Not a possible leap for some to make, but Isaac assured us after a few generations underground, these age-old notions would slip away and the new generation would adjust their lifestyle just as surely as we adjusted to smog and acid rain.

Still, only a select few are going to want to have anything to do with living on another world. And just as nature is selective as to which species get to survivee, so will Heinlein's *Harsh Mistress* be selective in her choices of those who will be first and those who will live on.

So as an architect, I listened to Isaac's words and tried my hardest to imagine a world where the surface is covered with nothing but trees, parks and farmland, and to save my life I couldn't come up with it. I felt sure that no one would want to live in the dark, dank earth. People need to be on the surface where they can look out of a window and see the sky and the trees. Now to be honest, there are a great many folks who currently look out of their windows on the world and see only concrete, asphalt, brick, steel and other forms of city scum. The sky they see is a gray filler between the tops of buildings. But still, I thought, they'll feel so trapped living below the ground!

Then I realized that countless citizens live at elevations so high that they are closer to the clouds than to the ground and that if any disaster strikes their particular building, such as fire or technical failure, these people will be locked into a desperate run down many flights of stairs to save very lives.

All things considered though, living underground still felt like a far-fetched idea and I decided that this time, Isaac was wrong. He sees the future more clearly than most of us today, but this time, he's surely dreaming.

Then I thought again of colonists on the Moon, living underground, and how life underground makes sense here on Mother Earth, but for different asons. I thought of Moon miners coming back from duty and wanting homes underground and how it would grow form there. And it hit me finally, that the old Doctor, might, after all, turn out to have been right once again.

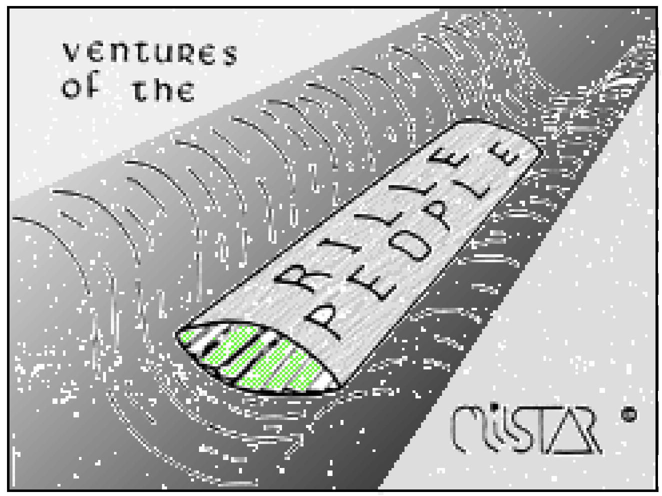
[Readers may refer to "M" is for "Mole" in our first issue. This is the lead-off piece in MMM Classics, Year I, available as a pdf file, and online at:

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

The issue of "bringing underground with us" both the scenic views and ample sunshine is the very crux of the article.]

Moon Miners' Manifesto #26 - June, 1989

At ISDC 1989 in Chicago over the Memorial Day Weekend, the Lunar Reclamation Society "Think Tank" **MilSTAR** team [**Milwaukee Space Tech & Rec**(reation)] won honorable mention for their design of **PRINZTON**, a 2-tier, 3-village, city in a rille just north of the mare-flooded crater Prinz, 10 km north east of Aristrachus. (see the cover art, page 1.) Our serialized entry begins here.



Prinzton

A Rille-Bottom Settlement for Three Thousand People

Part I: THE RILLE AS A SETTLEMENT SITE

by Peter Kokh

Rille: (pronounced rill) [Latin rima, a crack, cleft, or fissure] The origin of the word seems to be a German term for a brook or small stream. Observers of the Moon borrowed it to designate the many straight trenches (likely graben faults) and narrow winding valleys they found. The later, like Hadley Rille, are widely thought to be collapsed lava tubes.

I can remember the days when I used to look upon lunar rilles, great winding valleys hundreds of meters wide and deep and sometimes hundreds of kilometers long, as unfortunate road hazards, obstacles to easy transportation across otherwise flat lunar seas. Every time you plotted a logical route from point A to point B, sure enough there would be some lousy rille that would make it necessary to detour and zigzag or scout out altogether round-about routes. While I have a lifelong habit of staring apparent obstacles, disadvantages, and liabilities in the face until I see in them some hidden asset worth turning into a trump card, I was slow on this one.

In trying to imagine the Moon as a multi-settlement world, I have repeatedly scouted the maps, photos, and Moon globe for special assets unique to particular sites, giving them raison-d'etre [reason for being] as potential sites for human presence. The Moon is seen by most everyone as a dull monotonous place. But don't let yourself be fooled. The seeds for a diversified and varied human presence are there. *Clues abound!* Someday I'd like to write a book for amateur observers and armchair dreamers "Looking at the Moon with a Settler's Eye."

Nitrogen is the Stickler

Having plotted, in my mind's eye, a half dozen logical yet uniquely advantaged sites for traditionally conceived cities dug into the surface, I began to look further into the future to a time when one didn't have to be so stingy with nitrogen [Believe it or not, nitrogen for the inert component of air, not hydrogen for water and biomass, nor carbon, will be the most critical and decisive of the Moon's several deficiencies) and could plan a settlement with vista-friendly headroom. And so the idea of covering a rille finally burst in my lethargic brain. Covering a rille valley spanning as much as a kilometer, should not be an impossible engineering feet in lunar sixthweight, where there is no wind to blow and no quakes above an impotent 2 on the Richter scale. Building materials are already on site. But all the tons of nitrogen needed to co-pressurize such a volume! That's the stickler.

I imagined a long sinuous “national park” -- a wildlife refuge in which the then native Lunans could go to gawk and grok, in Schroter's Valley (not the 15 km wide main valley but the narrow rille within a rille that runs down the center - you need a good photo to see it). Maybe in the 22nd Century something like that would be possible.

Meanwhile, more modest structures could be built in rilles. Why? *Because rllles have sides!* It's as simple as that. Rilles have sides, that would otherwise have to be human-built. Why, *a rille is an excavated foundation just waiting for construction!*

In ***Welcome to Moonbase*** by Ben Bova (1988, Ballantine), Eagle Engineering's Pat Rawlings depicts large volume structures built on the Moon, requiring lots of excavation plus the hauling of a lot of shielding material up onto the clearspan shell. [The same drawings and art were used by the ill-fated Lady Base One Corp.] It was a bold yet quixotic concept.

Advantages of Rilles for Construction

In contrast, rille sites offer pre-excavated sites and *the opportunity to pull shielding soil down upon* any structure built in the lower portion of the rille. By virtue of its flanks, a rille site offers a vastly greater heat sink [the temperature of the soil below the first couple of meters is steady -4℉ = -20℃ all month long - all year long]. By the same token, from vantage points along the bottom, appreciable fractions of the sky that would otherwise be above the horizon are eclipsed by the rille sides. Consequently there is even less exposure to general cosmic radiation [Lunar sites, having their butts coveted by the soil below, have only half the exposure that space colonies will have].

Observation

Sinuous rilles often do not occur as isolated features. They are, after all, collapsed lava tubes. It is common to find a complex of rilles, partially collapsed lava tubes, and (by inference) uncollapsed suspected integral lava tubes, all radiating outwards down the gentlest of slopes from the principal sites of the great magma lava upwellings that filled the vast lunar impact basins forming the “seas” so familiar to us. A well chosen site should offer considerable regional expansion opportunities.

We have high resolution orbital photos of several such features. David Scott and James Irwin of the Apollo 15 landing mission explored a section of Hadley Rille from their lunar rover in late July, 1971. It was their photos that fueled my imagination. **MMM**

Next Month: Part II: Concepts for Rille Architecture

TOY CHEST

by Peter Kokh

On the Moon or in a Space Colony, will children's toys be imported? Most likely there will be severe restrictions - a matter of priorities - on which kinds of items such settlements can upport from Earth. During the early decades of scarce volatiles, the only luxury items that may be permitted in this up-the-well traffic are likely to be those made largely of strategic metals (copper, platinum, gold, silver) hard to extract economically on the Moon; of easily reduced simple plastics like polypropylene; and finally of biodegradable matter low in-oxygen (e.g. beeswax can be melted down at 145°F to be recast in new shapes).

The noble metals are very unlikely to make the journey as toys, even temporarily, since their urgent need is in industrial applications. Plastics are the subject of the following article. Beeswax and other waxes are more likely to come as packing material rather than pre-molded miniature animals, astronauts, or phaser guns. It is quite clear there will be no TOYS-R-US in either a Luna City or some New Tucson colony at L5.

Rather the settlers will have available to than a limited inventory of toy stuffs and will learn to do quite well within such limits, as have all peoples before the current consumer paradise. Considering that toys in general are rupture-active with a half-life of about a week after purchase, there might be some relaxation on using soft wood from trees grown in the frontier community, provided it is not fouled with treatments of any sort (e.g. stain, paint, varnish) that would prevent its being eventually biodegraded. A good use of wood would be for modular toy construction kits: Lincoln Logs and Tinkertoys etc. (curious wonders of long ago). If silicon-saturated rubbers can be formulated, toys as well as tires will employ them.

Other biodegradables that can do 'detour duty' as temporary toys, in addition to the moldable and carvable beeswax already mentioned, are corncobs and husks - used by many cultures, seeds, kernels, and nuts for toy jewelry, beadwork, and mosaics; egg shells for decoration; and for modeling, organic play-doughs made from flour, water, salt, and sometimes baking soda. Helping the cook prepare such fancy but transitory table fare as decorated cakes and gingerbreads can serve a creative play function; and so can simply arranging given colored items about the home in pleasing still-life creations.

The cuddliest stuffed animal is a living non-stuffed one [see "Animal Life" in MMM # 8 p.6]; and in a world ungraced by outdoor wildlife, pets will be especially important. But for artificial substitutes, space frontier folk should be no more hindered by the unavailability of soft foam, pliable synthetics, and other modern toystuffs, than were the hardy pioneers inhabiting Earth in more rugged times. Old clothing (to be reborn as rag dolls and rag animals) and such items as raw cotton, seeds, corn silk, feathers, even shorn human hair can do toy duty.

Yarn seconds and looms should be available. Wood, wax, soap, even potatoes are fube for temporary carvings. Recyclable home craft papers for wax crayons with unprocessed vegetable dyes or for water paints of the same simple composition present no problem. A library of books on old folk arts and crafts, toys, dolls, and games, should be of more than historical interest and inspiration to pioneers of this new frontier.

Toy vehicles (hopefully soil-moving equipment, prospector 'jeeps', over the road rigs, and sundry spacecraft rather than battle robo-tanks) can be made of cheap sintered or die-cast metals as they were prior to mid-20th-century before plastics became king. But all toys should be modular in construction, with parts that snap together in a variety of ways to develop the child's imagination, rather than specific fixed adult-designed offerings that disable the immagination. Board games will see cardboard and plastic replaced with glass, glass composites (GLAX*), ceramics, and sintered iron, enticing the craftsman to produce them with heirloom quality.

In general, however, given the small population and market, the selection of finished, ready-to-play-with toys available to the pioneer shopper will be small. Kits out of which a variety of such toys can be created in the exercise of one's imagination will be the rule. This will certainly be one of the healthier facets of the micro-market economies of the space frontier. But as the number of mutually trading frontier settlements grows, this wistfully idyllic situation could change.

Recycling will be 'the fourth R', a necessary ritual for the settlers, quintessential to their survival and prosperity. In large measure, the collection and primary sorting of recyclables will be the duty/chore of older children. It would be natural to scavenge such binnage for items with toystuff potential. And so when it comes to making finished toys, this enterprise may be left to the more artistic and craft-handy among these older youths with the younger children as the beneficiaries. This would help keep most adults free for the more pressing productive needs of the community.

MMM

THERMO PLASTIC

Subsidizable import for many uses

by Peter Kokh

Although it is rich in oxygen locked in its soil and rocks, the Moon is volatile poor, very poorly endowed with the other life-supporting elements: Hydrogen, Carbon, and Nitrogen. There is indeed a reservoir of these gasses *adsorbed* to the fine particles of the lunar soil through eons of incessant bombardment by the solar wind [see "Gas Scavenger" in MMM #23]. While we will certainly 'mine' such reserves to the extent that the methods for doing so are cheaper than wholesale upport from Earth, we will probably need more of these elements necessary for water and biomass than we can extract from routine soil-moving construction projects or as a by-product of mining operations.

[The high cost of such vital elements will provide a strong motivation to develop the small Martian moons, Phobos & Deimos, thought to be rich sources of hydrocarbons. Despite their distance, the fuel needed to fetch volatiles from these two low-gravity worldlets is but a third that necessary for upport from nearby Earth.]

These same elements are basic to most plastics (nitrogen is used mainly for nylons; same plastics involve chlorine and fluorine). Until hydrogen and carbon become dirt-cheap on the Moon and Moon-supplied space colonies, it will be rather uneconomical to make anything of plastics that can either be made of something else, or simply done without. This will be the case for the early years on the space frontier.

In general, plastics fall into two broad categories. Thermosetting plastics, commonly based an urea resins, set when heated and cannot be remolded. The only way to recycle items made of thermosetting resins is to incinerate them. Incineration, in small totally closed environments such as a space colony or lunar settlement, could only be permitted if it was so thorough as to emit nothing except water, carbon dioxide, and benign recoverable ash. The standard of absolute purity required, would be difficult to realize in any economical way - though Earth's own need will drive experimenters to work towards this elusive goal. An expensive compromise would be to incinerate such items in a facility isolated from the rest of the settlement biosphere, recover scrubbed steam and carbon dioxide, and exhaust noxious emissions to the outside vacuum to be carried away harmlessly by the solar wind, but forever lost to reuse.

The only alternative to incineration is simply to discard items made of such materials, thus permanent banking - and wasting - their precious exotic (exo-lunar) content. This very high volatile replacement cost for thermosetting plastics will demand that they be absolutely reserved for those very few items that can in no way be made of any other material. Esthetics, ease of manufacture, through-color, light weight, easy-care and other luxury considerations will be no match far the harsh reality of lunar biosphere economics.

Ninety percent of everyday plastics, however, belong to the second category: THERMOPLASTICS. These materials set through cooling, and can be either reheated and remolded, or shredded and refused. In other words, thermoplastics are recyclable if need be, and *the need will be* on the early frontier.

Nonetheless, four observations are in order. **First,** even if recycled, thermoplastics tie up elements that could be used to increase the size of the biosphere to make it healthier, more self-maintaining -- *the* priority. Despite their ability to be recycled, thermoplastics should only be used on the frontier when wares of non-exotic composition (metal alloy, glass, glass composite, ceramic, etc.) would make totally unsatisfactory substitutes.

Second, to have efficient recycling, it is indispensable to have error-free easy sorting of materials of different formulations. The surest way to do this would be color-doping according to a set assignment-protocol. This would mean forgoing all the neat tricks manufacturers use on Earth to disguise the character of materials and thus defeat recycling in advance. This stricture will be accepted, once the benefits of materials-honesty are seen. While in general, each kosher plastic with a mainly functional use would be available in only one hue, a formulation chosen for children's toys could be made in a full spectrum of colors *IF it was further distinguishable,* for example, by brightness, translucency, or iridescence. A color protocol can be applied with same versatility.

This and similar protocols of materials and surface treatment honesty designed to insure idiot-proof recycling ease, while designed to make lunar type civilization workable, will offer invaluable appropriate-technology spinoffs to Earth's throw-away society. Remember this when next you hear some dolt whine about space nuts wanting to pollute the universe.

Third, having to give up a plethora of plastics and other synthetics has a strong positive fringe benefit: substitutes made of the inorganic materials on hand will not burn. Fire cannot be allowed in the closed environments of a space colony or a lunar settlement. There are no cubic miles of fresh air overhead for flushing out the smoke. Even the smallest fire must be avoided like the plague. When cheap sources of volatiles and efficient transportation finally make plastics and synthetics an economical choice, space pioneers will be wise to continue to do without them rather than play Russian Roulette with their safety. [Mars, blessed with the elements the Moon lacks, will be the tempting exception, and it may take a catastrophic but hopefully small fire to drive the point home.] By the same token, those thermoplastics which are allowed when substitution is impractical, must be formulated to be incombustible and/or to have NO toxic combustion by-products. A low outgassing rate is also important.

Fourth, the production of plastics commonly involves byproducts (often toxic) for which no use is readily found. Thus it will be far cheaper, considering transportation costs alone, to have admissible plastics produced where the raw materials are (Earth, Phobos etc.) than to import raw feedstocks only a portion of which will end up in the ultimate product. Basing a synthetics industry on feedstocks of plant resins, waxes, and oils homegrown on the Moon saves nothing if the hydrogen and carbon involved has to be brought in from elsewhere in the first place. Only those lunar agricultural products which incorporate lunar-sourced oxygen and/or silicon provide savings over imports.

The Cheapest Method of Entry by far for protocol-meeting protean thermoplastics will be not as ready-to-use-items but either as packing and packaging materials, or as replaceable items needed aboard the cargo vessel for the trip to the Moon but not for the return to Earth etc.

If the non-combustible standard can be met, polyester and polypropylene may see the widest variety of uses, especially for non-durable uses for which inorganic materials are less suited. Future Articles will look at specific areas in which such plastics may be part of the solution along with ingenious use of inorganic materials.

BIODEGRADABLE PLASTICS TO THE RESCUE?

A recent article in ***Science News*** [May 6, '89; Vol. 135 pp 282-3] reports on recent attempts to marry starches to polyesters and polystyrenes to provide serviceable plastics that can in effect be anaerobically composted. The starch content, varying upwards from 6-40% (the goal of the experimenters being 60%), gives an avenue of attack for microorganisms. In the process, up to 15 percent of the 1200-carbon-long polyester molecules slowly decay into non-toxic 25-carbon waxes similar to those forming naturally on apples.

Garbage bags made of the new material should be on the market within a year.

Terrestrial Spin-up Opportunities

Incentives to solve the “plastics problem” are strong. Plastics currently account for 7.2% of solid waste by weight and 32% by volume with only 0.5% being recycled. But the admitted driver for these experimenters is to find new markets for corn by-products, i.e. starch. That's fine. It's how the system should work.

But a strong caveat is in order. This so-called 'decomposition' may break down films and other plastic items, but until hybrid plastics are made for which the decomposition is thorough, and until byproducts are produced that are actually taken back up into the biosphere cycle, available for food production etc., such processes which promise a bit of relief for some Earth-bound waste disposal headaches, will not necessarily make these new hybrid plastics good lunar citizens. On the Moon or space colony where hydrocarbons will likely be expensively acquired, they must be recycled full-cycle. So far, the progress achieved in producing "decomposable" plastics has only resulted in a more subtle form of out-of-sight-out-of-mind disposal method that involves indefinite 'banking' of much of the hydrocarbon content. But it's a start in the right direction! **MMM**

Moon Miners' Manifesto — # 27, July, 1989

FOOTWEAR

by André D. Joseph and Peter Kokh

How settlers might provide for their footwear needs without surrendering helplessly to the expensive upporting of catalog-ordered shoes from Earth, may not seem the most pressing problem facing them. But tipping the balance of the import/export ratio in their favor will depend significantly on attention to a whole host of details. Footwear is such a detail.

Leather is protein and contains carbon, hydrogen and nitrogen. It also contains oxygen which can be sourced locally. Thus leather produced on Luna, all else being equal, will be proportionately less expensive than upported leather. But leather is normally produced by chemical tanning which will be unwelcome in small closed biospheres of the space frontier. Instead, depiling should be mechanical, rather than chemical. The possibility of using readily avail-ble untempered solar ultraviolet rays for curing is an option worth investigating. This could be done in a near-surface pressurized facility with an unshielded ceiling of quartz panes. Unlike glass, quartz does not block UV.

Investigators should bear in mind that hides from rabbits, cavies (guinea pigs), and goats will likely be more readily available than cowhide. Genetic engineering may someday allow cultured cure-friendly hide to be grown in vats, without the animal. Above all, the end product must be something that can be biodegraded at the end of its service life.

Synthetics, -- especially those containing little or no oxygen, are better produced on Earth, especially considering the waste products of their manufacture. Those synthetics which are thermoplastic, i.e. which can be remolded or shredded and re-fused, might be an acceptable way to provide the desired flexibility and resiliency. Polypropylene comes to mind.

Settlement production of synthetics that are rich in native silicon, all else being equal (recyclable, non-flammable , without toxic byproducts of manufacture) promise to be an attractive alternative, for both soles and heels. **Silicone** chemistry is one of those fields in *dire need* of further development by chemists who want to speed the day of lunar self-sufficiency.

On the one hand, the need for resilient soles will be less, given the one-sixth gravity. On the other hand, as it will be enormously more efficient to provide resiliency in shoe soles than in volatile-voracious carpeting and carpet pads, the role of shoe soles will be very important. Much greater attention will have to be paid to tread as well, since in sixthweight, traction (starting, stopping, turning) will be proportionately reduced.

Economics -- the high price tag on the upported non-native (exotic) content of shoestuffs -- will affect shoe design greatly, by confining materials chosen for resilience and flexibility to those shoe parts where these assets are most needed. Tall *boots* seem to be the universal choice of science fiction film producers. But in reality, their use will most certainly be confined to the heavy-duty work situations where generous helpings of such materials are justified and for which there may be no easy alternative to the upport of suitable specialty foot gear from Earth.

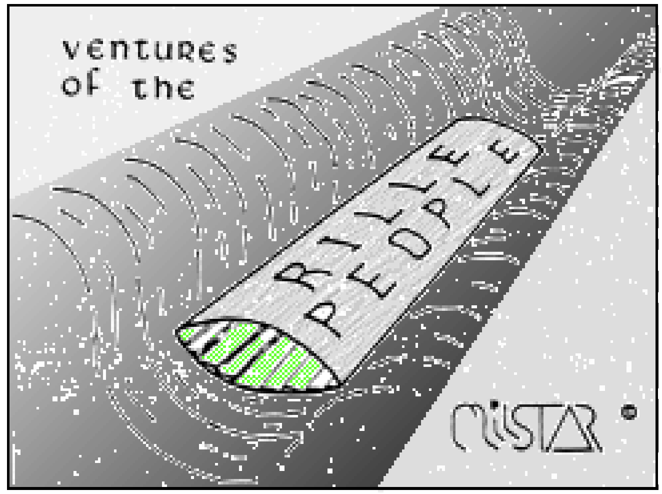
Sandals -- (with or without cotton socks) seem a quantum leap more sensible for most other use, In this scenario, sandal uppers would be the principal medium of style, fashion, and variety, Cheap cotton laces, thongs of unprocessed gut, chain and chain mail, glass bead decorated bands, macrame fantasies and woven fiberglass straps, are among the many possibilities, giving ample room for creative cottage industries.

One-piece uppers could be made in canvas, denim, flannel, muslin, velveteen, terry, felt, and other all-cotton fabrics, to be purchaser-decorated. There'll likely be a design re\quirement that uppers be readily detached from bottoms for ease of recycling the materials involved: kosher assembly, if you will. Interchangeable uppers would allow expensive sole and heel materials to stretch much further.

The authors are open to other suggestions, but remember that only fairy tale princesses can wear glass slippers. **MMM**

Continuing our Report on PRINZTON

a 2-tier 3-village rille-bottom settlement for 3,000 - 5,000 persons



Part II: RILLE ARCHITECTURE - GENERAL CONCEPTS - Peter Kokh, Mark Kaehny, Myles Mullikin, Louise Rachel

A. Atmospheric Pressure: a Supercritical choice. Perhaps it is because most of today's exo-habitat designers have came to the space movement in the post-O'Neill era that so many of them seem to be what can only be called Earth-normal chauvinists. Without ever examining the potentially onerous consequences, they predictably specify, with a casualness more appropriate to choice of color, that their habitat design calls for Earth-normal atmospheric pressure and, where possible (as in space colonies), Earth-normal gravity. On the other hand, old-timers who have been space advocates long before O'Neill's watershed articles on Space Colonies, and who were reared instead by the likes of Arthur C. Clarke, Robert A. Heinlein, and others, are far more likely to put considerable faith in human adaptability.

The choicd of atmospheric pressure is perhaps the single most critical design specification for an exo-habitat. There are two reasons for this. First, the propensity to spring pressure-caused leaks rises exponentially with the pressure. If you wish your habitat to be as maintenance free as possible, this should definitely be a nontrivial consideration.

Second, the inert gas nitrogen which accounts for an unnecessary 79% of Earth-normal atmosphere is in far shorter supply (as compared not only with oxygen which is abundant, but also with hydrogen and carbon) in most solar ystem locales except Titan. If one is talking about close-ceilinged habitats with the minimal mass of atmosphere per usable square foot of floor space, nitrogen is already the pacing deficiency if one's native sources for volatiles are the soil moved in the construction process. [See "Gas Scavenger", MMM # 23 March '89]. Even though the needs for hydrogen (water, biomass, industry) are obvious and we are rightfully attentive to the problems of economical sourcing of this primordial substance, the potential import cost for nitrogen is even greater.

Now if this is already the case for close-ceilinged habitats, imagine what happens when you specify a generous headroom and vista-providing clearspan. Hydrogen and carbon needs will remain steady as they are more determined by square footage/ acreage of habitable space. But when overhead space is more generously provided either for postcard views or better dilution of whatever undesirable emissions prove to be unavoidable, the cost of providing needed nonnative nitrogen soars.

We have frequently mentioned the Moon's need to develop non-terrestrial sources of the volatiles it lacks. Nitrogen will be at the top of the list, and the hydrogen needed is logically co-imported as ammonia (NH_3) or methane (CH_4) than by itself (H_2). The single most effective thing we can do to cut the cost of imports lunar or space settlements will need to survive is to design out excess nitrogen.

It is for this reason that the MilSTAR design team chose to go against the flow and specify half-normal atmospheric pressure BUT with Earth-normal oxygen partial pressure. This results in an atmosphere which is 42% oxygen and 58% nitrogen with all the savings born by a 62% cut in the nitrogen import burden.

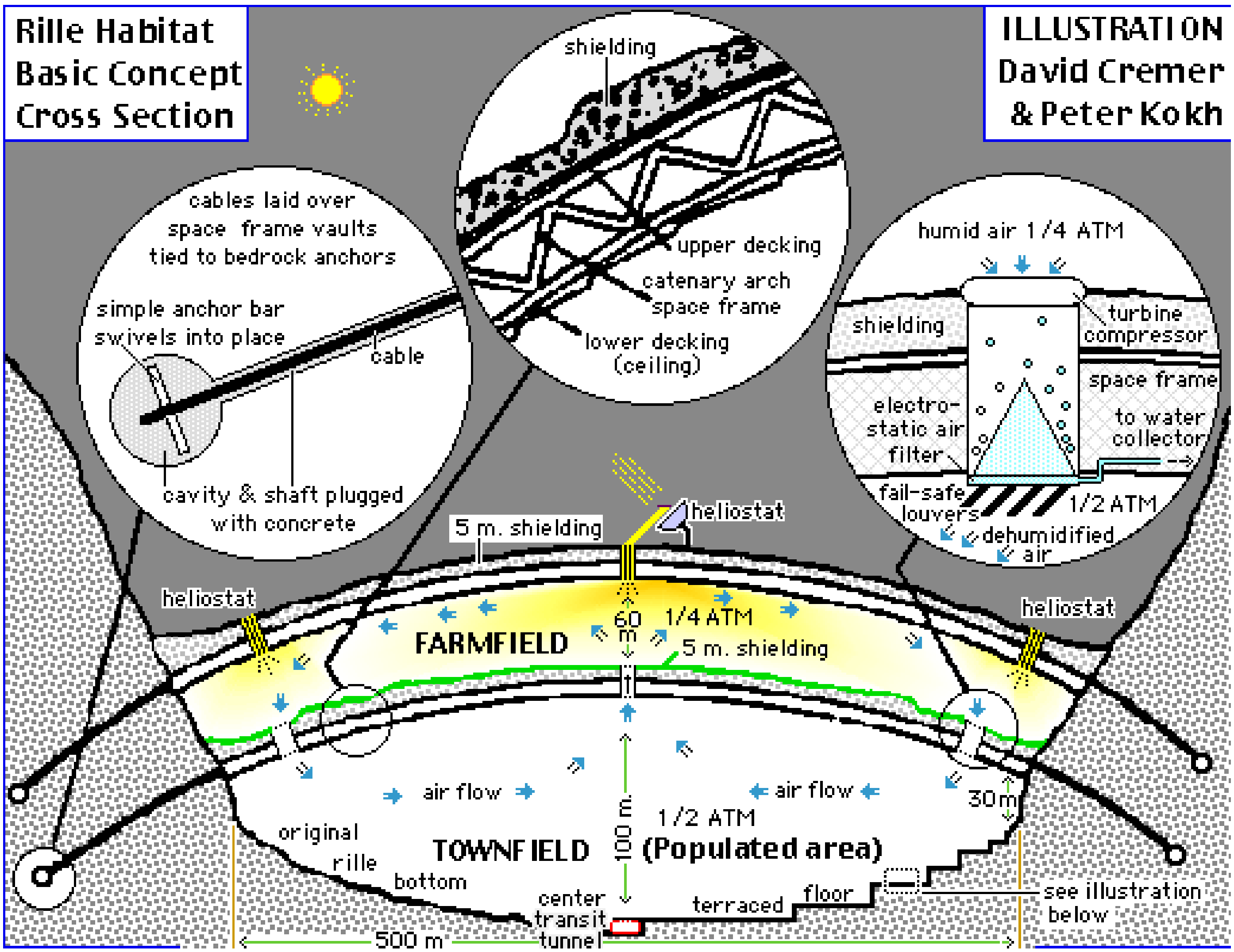
A common objection would be that we are increasing fire hazards with this much oxygen. But the amount of oxygen is no more than we are used to on Earth. It only appears to be excessive in contrast to the reduced nitrogen component. The O_2 partial pressure remains the same and it is that, not the O_2/N_2 ratio that determines fire hazard. An objection seldom raised which we are far more concerned about is the possibility that the new ratio will result in a higher amount of potentially carcinogenic and tissue-degenerative free radicals. The answer awaits further research deserving of the highest priority given the make-or-break stakes.

Perhaps more than any other single design choice, the specification (implicit or explicit) of the amount of nitrogen needed will determine the economic feasibility of an exo-habitat design. If we are at all sincere about human outsettlenent of the space -phere makeup and pressure specs for biospheres in free space or on the Moon. The present ho-hum lack of attention to this supercritical point does not say much for space advocacy. We recommend that Space Studies Institute, the research arm of the movement, push this study.

B. Choice of a Two-Tiered Structure -- In designing our rille-sited habitat for 1000-5000 persons (NSS competition specs), we tempered our desire for spaciousness and vistas, not only by specifying a significant cut in the nitrogen co-pressurant, but by vaulting over only the bottom of the rille, rather than capping it shoulder to shoulder. In addition, mindful that plants are less demanding than people, our design calls for a two-tier structure. A **townfield** at the bottom of the rille enjoys the O.5ATM (1.0 Earth-normal oxygen) just described. Suspended above it by the difference in air pressure is a **farmfield** (with less generous headroom) that has 0.25ATM with the same mix of gasses as below (hence 0.5 Earth-normal oxygen). This would be a largely automated agricultural area. The workers needed to tend this farm area intermittently, would be unmasked but supplied with a back-pack oxygen tank and a mouth tube which they could activate by sucking on as needed.

The warmer, moister, but vegetation-freshened thin air of the farmfield would be exchanged with denser, cooler, staler townfield air by (downflow) fail-safe turbine condensers (which would also turn the humidity into potable water) at the rille sides and by (upflow) electricity-generating heavy-load fail-safe turbines along the high point of the vault-span.

Both vaults are space-frame type strut structures in the shape of the shallow portion of a catenary arc (the shape of a hanging chain) - the strongest shape in both compression and tension. [The St. Louis Gateway Arch s an example.] These vault frames would be decked both above and below, with cables overlying the topside tied to bedrock anchors in the side of the rille. We specified five meters (16 ft) of settled lunar soil shielding (specific gravity 2.6 gm/cm3) above both vaults which would nearly but not quite

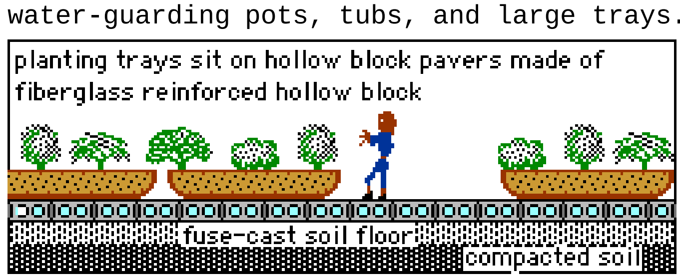


neutralize the air pressure below, leaving a modest 51 gm/cm2 (0.72 lbs/in2) upward thrust [keep in mind the 1/6th gravity situation]. There would be somewhat more shielding near the rille sides so that at the point of attachment, net weight-above vs. pressure-below loads would be zero.

The vault-frames need not be built to carry uncompensated loads from either shielding or air pressure. Instead, once decked and sealed, the volume below would be pressurized gradually to keep pace with the on-loading of shielding soil above. In the unlikely event of a failure to maintain the pressure differential that supports the lower vault, it would be suspended by normally slack cables to the upper vault. The increased air pressure on the upper vault in this situation, would more than support the weight of both.

The combined depth of shielding above the townfield area is some 10 meters (32’) which far exceeds requirements for radiation and micrometeorite protection. Significant puncture of the upper vault would not be expected on statistical grounds in a thousand year time frame - a much longer span than any Earth city design can offer.

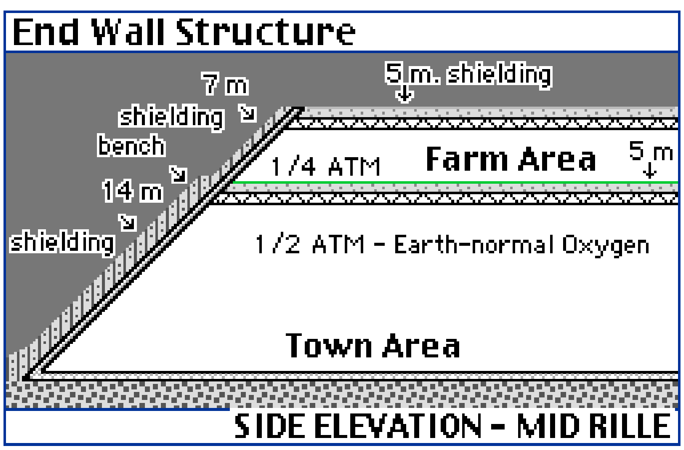
The rille bottom would be terraced following computer-suggested lines to need a minimum of soil moving. The flattened and compacted terraces (perhaps reinforced with fiberglass mat), and vertical surfaces would be microwave-fused to a depth of half a meter and then sealed by laser-glazing. Thereupon the terraces would be paved with hollow blocks or slabs to provide both runs for utilities and an insulating air layer. The resulting surface would serve for walks and roads with all plantings in water-guarding pots, tubs, and large trays.



C. End Caps for 2-Tiered Rille Structures.

Obviously, our structure has to have a beginning and an end. At first we considered some sort of vertical air dam since early on we decided to segment the settlement so that it could be built and occupied one 'village' at a time. We had hoped to come up with a barrier which would serve to end one segment and begin the next. However, there seems no way to build such a vertical barrier strong enough to withstand the pressure differential between 1/2 ATM and vacuum over such a large expanse (500 meters wide by 100 plus high).

The solution was to bring the soil-loaded (pressure-compensating) roof down the ends on a 45o slope. This sloping end-wall would have vertical baffles to hold soil shielding in place. Some 7 meters of shielding along the upper slope would supply the same loading in a vector perpendicular to the slope (inward to the farm area) as does the 5 meters on the upper vault. And 14 meters of soil on the lower slope portion would give the same loading vector against the greater atmospheric pressure in the lower tier as the combined 10 meters above both vaults. Thus we have a wall which is also a roof, and it works. This end slope wall would likewise have a shallow catenary convex shape and also be cable-tied to bedrock anchors. A solution with no weak spots is the result, although it meant that each village-segment would stand alone. The end of one could not serve as the start of the next.



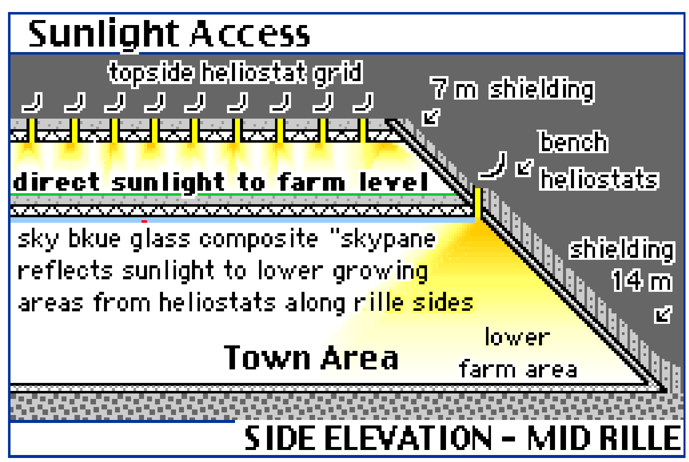
D. Bringing in the Sun.

We had already chosen an east-west section of rille so that the full fourteen days plus that the Sun is above the general horizon would be available to our villages. In a north-south rille, our bottom hugging settlement would be shaded by the rille side slopes for unwelcome stretches at the start and close of each local lunar 'day'.

Sun-tracking heliostats, concave mirror devices which concentrate the sunlight and channel it into the habitat below, would work well for the upper vault area, the primary agricultural acreage within the settlement. We came up with a low-tech design that does the job neatly enough. The low-tech approach is critical because many hundreds of such devices will be needed and our settlement must be able to manufacture them on the spot.

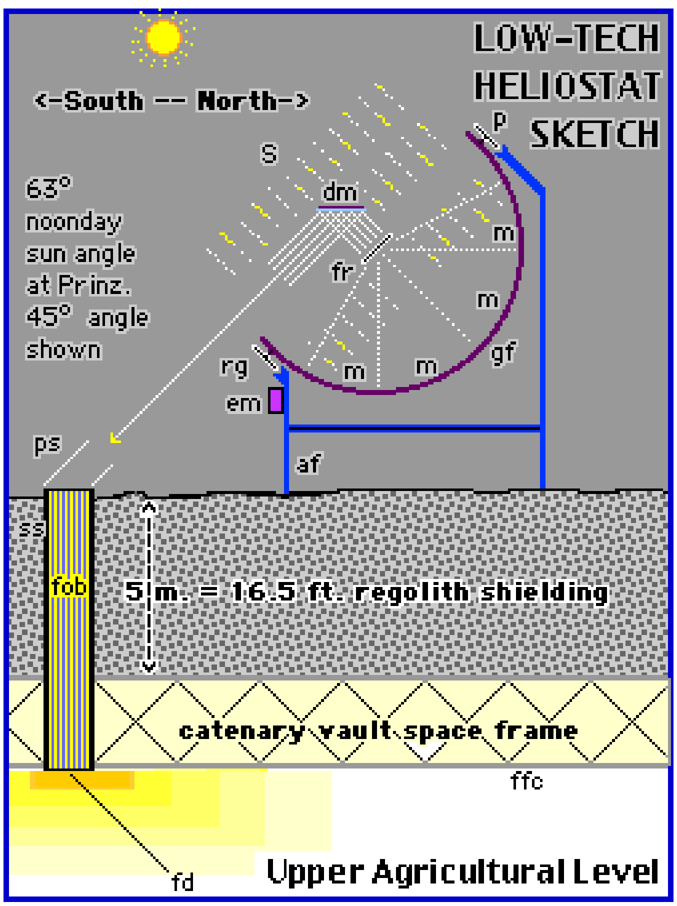
At the point where the sloping end wall meets the lower vault and the shielding increases from 7 to 14 meters, there is a 'bench' along the shallow curve of the end wall where an additional row of heliostats could be placed that have direct access to the end areas of the lower habitat area. This will mean these areas should also be dedicated to agriculture, especially to crops that need to be tended more often.

For the main central stretch of the lower 'townfield' area, we decided upon a different approach. Heliostats along the sides of the rille would channel sunlight down shafts to a point where it could be reflected off the vault ceiling. The lower vault would have ceiling panes of glass composite [Glax*] that could be ribbed to catch and scatter this reflected light. They could also be formulated to have a sky-blue cast. A pleasant ambient light from a bright blue sky would thus pervade most of the lower residential area. Garden plots needing more intense lighting could use electric task gro-lights suspended over the beds, thus not wasting light where it isn't needed.



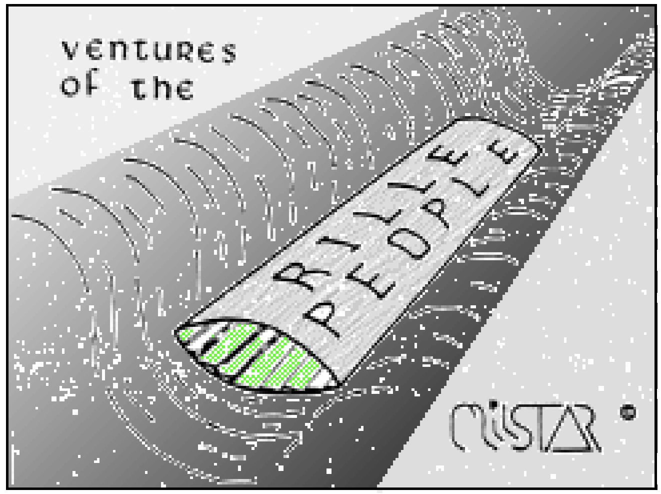
What about the night? This is a dual question. First during the local two week sunshine periods while farm areas above may want to use all of this, the residential areas below are free to shutter the light shafts to provide 'nighttime' on a 24 hr cycle. Second, during the local two week nightspan, the same sunshine delivery system can be used to direct light from efficient large electric lamps, via the heliostat optics and via the shafts that bounce light off the reflective skypanes.

A LOW TECH HELIOSTAT DESIGN: a **dm** diagonal mirror which receives **S** sunlight from **fr** fresnel rectifier collected by flat **m** mirror segments mounted on a **gf** geodesic frame bowl rotating on a **p** pivot and a **rg** ring gear driven by an **em** electric motor on a stand with **af** adjustable feet. Sunlight is then channeled by a **fob** fiber optics bundle that allows a direct path while maintaining shielding. Bundle sits loose in **ss** shouldered sleeve with a **ps** protective shroud. Light passes through open **sf** space frame to **fd** fresnel diffuser set in the **ffc** farmfield ceiling, to spread a cone of light on field below. Heliostat turns all through the month (360o) so that it points at the ground at night to minimize mirror exposure. *NOTE: The sketch below shows the axis incorrectly.*



Moon Miners' Manifesto #28 - September 1989

Continuing our Report on PRINZTON
a 2-tier 3-village rille-bottom settlement for 3,000 - 5,000 persons



Part III: INDUSTRY & the 3 VILLAGE SYSTEM

Peter Kokh, Louise Rachel, Mark Kaehny, Myles Mullikin

A. Two Broad Classes of Industry

A principal requirement of our design is that Prinzton supply both the great bulk of its own needs and sufficient exportable commodities to pay for what it must import. Open to further diversification as the settlement matures, the initial list should look like this:

- **Oxygen** - export for rocket fuel -export and domestic for making water and for air. Oxygen comprises 50% of food tissues by weight and 89% of associated water. Abundant native lunar oxygen is what makes lunar food growing attractive. Staples grown on the Moon would eventually have the price advantage over similar items from Earth *delivered to low Earth orbit* and other space destinations. That is, in time, Prinzton could became a food-exporting settlement (if the considerable problem of supplying nighttime agricultural lighting is solved favorably). Foods that had to be imported would be freeze-dried as this would at least prevent import of the oxygen of the water of hydration.
- **Sintered Powdered Iron Products** - iron is available by reduction of ilmenite (an iron and titanium bearing ore) and other minerals. However, free unoxidized iron fines abound in the loose regolith

'topsoil' of the Moon and are available for the price of a magnet. As soil is moved about in the construction process, routine magnetic scavenging will yield many thousands of tons of pure iron.

Sintering such fines into useful products can be done easily and simply by well known, and widely used, powdered metal technology. While sintered iron will lack the tensile strength of steel, for many unsophisticated applications, it will do quite well. And unlike steel-making which is an elaborate process less suited for the small (by Earth standards) settlement, sintered iron is an ideally appropriate starter technology.

Many of the more massive parts of the needed construction equipment and other tools could be fashioned locally for final assembly on site, thus cutting the required import tonnage considerably. This promise is what gives sintered iron its high industrial priority. And of course, sintered iron building products will be used in the construction of Prinzton itself.

- **Glass-glass composites** (Glax*) - Very much on the analogy of fiberglass reinforced plastics, so familiar and so versatile, will be glass fiberglass matrix composites made wholly from lunar regolith 'soils'. A technology still in the early stages of laboratory development under the aegis of Space Studies Institute, it should be ready to go by the time we return to the Moon to stay.

  Glass composite production could begin even with the first token outpost, able to yield unsophisticated building products suitable for shelter construction and tankage. As settlement grows, this ideal starter technology should quickly diversify for the production of export-quality building elements for use in in-space construction as well as for the advanced construction requirements of Prinzton itself.

  By varying formula-tion and production techniques, settlers should be able to use this new class of materials to substitute for wood in furniture, for synthetics in small appliance and electronics casings, for vehicle body panels etc. Glax products for export should quickly diversify, again thanks to the price advantage for delivery to allspace locations.

- **Concrete** - will be a very useful building material choice on the Moon, especially if local water reserves are found in the form of permanently shadowed polar ice deposits, or if ways to import hydrogen cheaply are found. If neither is the case, concrete will be reserved for applications where its especially appropriate qualities outweigh the high cost of importing hydrogen to make up the needed water. As an export commodity, concrete may be useful for shielding requirements of some types of space installations. Again, lunar concrete - even if expensive - will be at a significant price advantage over Earth-produced concrete.

- **Cast Basalt** - is a technology reputedly in use in Central Europe (although this writer has been able to find no further information i.e. where, how, for what etc.). Paving and landscaping slabs and barriers where minimum strength is required could be made of this low-cost melt-and-cast material.

These will be the **Basic Industries**, able to support considerable product diversification for both export off the Moon and to other lunar sites, and for domestic consumption. The raw materials should be available locally for the most part. The need to import necessary trace ingredients, that may not be economically sourceable locally, could conceivably support a number of smaller mining communities elsewhere on the Moon at specially endowed sites.

In our design of Prinzton, we took these industrial functions of the settlement into account in two ways. First we divided industrial activities into two broad categories:

- **Heavy Industries** - those involving high heat output, requiring direct sunlight, requiring vacuum, and/or involving vibration that could compromise airtight structural integrity. These we sited above the rille on the broad shoulders. Workers would commute from the habitat areas in the rille bottom via pressurized tubes and s.
- **Light Industries** - which involve acceptably minimal heat production, need only electricity, and involve near-zero emissions: machining, and light assembly and finishing type industries; some food processing. These industries are suit-

able for siting within the principal habitat area, i.e. the 'Townfield' or lower level of the two-tiered village habitat structures.

Second we paid at least some attention to the order in which industries would be needed, and the logical order of diversification. Thus the first village would have more basic industries than subsequent ones. To add to the minimal variety and diversity of consumer products that such a small population (1000-5000) could provide for itself in its principal industries we foresee the rise of considerable spare-time* cottage industry enterprises and flea market areas to serve them.

[* In the beginning, every able-bodied person will be principally involved in production aimed at export or at basic domestic construction and necessities.]

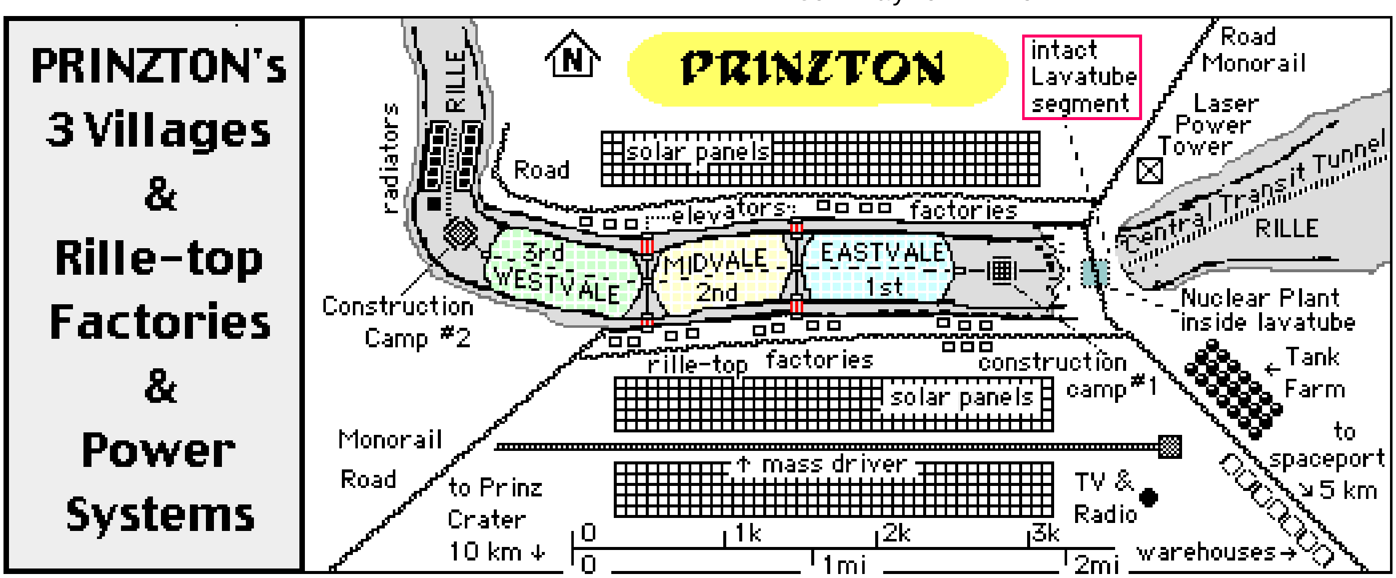
B. The Choice of a Three Village System

Laid-back and inefficient lifestyles may be manageable Earthside, though not without inevitable penalty. But on the Moon, a settlement will not "make it" unless it is industrious to a fault. Much of the industrial machinery and tooling the settlement will need will be well beyond its capacity to self-manufacture. Equipment imported from Earth at very high cost can not be allowed to rest idle most of the time. A three shift system of production scheduling (or the even more efficient four crew two shift 3-4-4-3 system used in the beverage container industry which doesn't stop for weekends) will be necessary. Some of the design crew held to idealistic objections to the social consequences of shift-scheduling all the same.

Meanwhile, we were already committed to a 'segmented' settlement of physically separate village habitats that could be built one at a time 1) to allow earlier occupancy, 2) to distribute rather than share risks of structural failure, 3) to allow incorporation of new building materials, methods, and systems into later villages. We had no set number in mind.

In a eureka flash, it occurred to us that with three villages, each on its own day-night lighting scheme staggered eight hours apart, production scheduling could be handled rather elegantly. Each of the villages would in turn man/staff/crew all the production facilities - even schools and shops - not only within its own industrial park and enterprise zone but within the other villages and on the rille top as wall, in its allotted shift. When the 'A-villagers' finished, the 'B-villagers' would take over, etc. Meanwhile, within each village everyone would be on essentially the same schedule, allowing maximum social interaction during off hours. 'Night people' could do their after-hours recreating in another village, and so on. This is a scheduling solution that is not available to unitary settlements, including solitary space colony cylinders or spheres (though this feature could be incorporated in torus-type colonies).

Multiple villages also allow the opportunity for very welcome change of scenery, as each could have unique layout, landscaping, architectural style mix etc. and thus its own unique ambiance. Finally, multiple villages lend themselves to more interesting sport rivalries. Thus the three village system is central to the Prinzton way of life.



SARDINE CAN Fatalism

by Peter Kokh

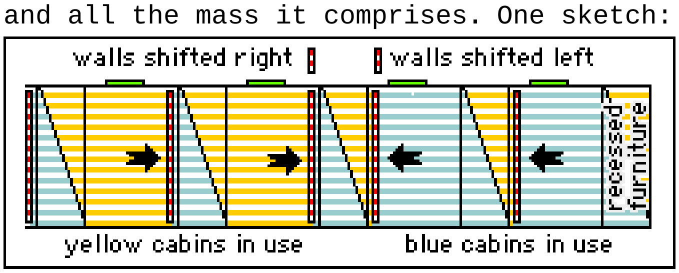
July 20, 1989 Milwaukee, Wiscsonsin - The University of Wisconsin-Milwaukee (UWM) has received a 3e-year $105,000 grant from NASA's Universities Space Research Association, to build on its (UWM's) previous work in designing a a Lunar outpost to include manufacturing, laboratory, and habitat space. The renowned UWM Center for Architecture and Urban Planning Research will direct the project in cooperation with the UWM College of Engineering and Applied Science, according to Center Director Gary T. Moore.

According to Moore, the UWM students face the challenge of making the habitats livable despite "the need to make them as small as possible." While Moore recognizes the need to provide get-away-from-one-another elbow room space for the ten or so persons stationed at the base, the NASA "sardine-can" approach is rooted in the agency's unwillingness to look beyond the deployment period in which everything *must* come from Earth in some payload bay or faring-space.

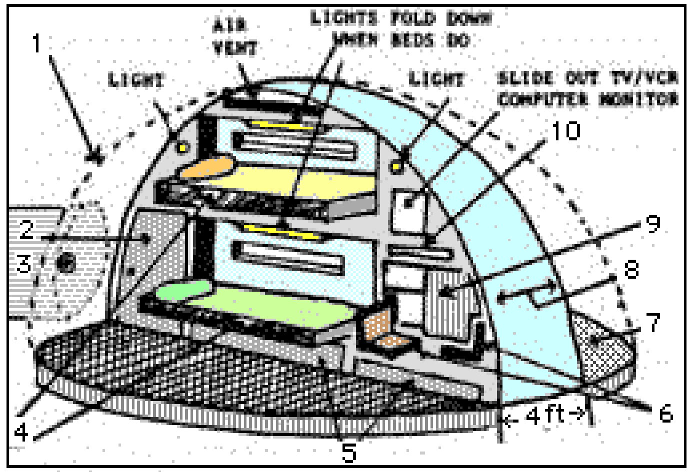
Moon Miners' Manifesto, also in Milwaukee, holds to the brash declaration of "Miners' Rights" implied in "Manifesto," and will continue to illustrate alternative options and to outline lines avenues of research that will create a frontier lifestyle that is both truly human and truly lunar.

One thing we hope the UWM group will consider, is an option of pairing private quarters on an alternating shift basis, with a two-sided works core sliding into the unoccupied walk-around space. A "works" core-modules would contain plumbing conveniences, climate control, communications and entertainment centers, etc., and possibly built-in fold-out, slide-out, pop-up, or pull-down furniture.

Once we are able to build habitat modules from local materials, these core modules could still be imported from Earth, without the original pressurized container and all the mass it comprises. One sketch:



Below is another illustration by Dan Moynahan, our MLRS resident artist.



KEY: **1** Recycled fuel tank shell half or more spacious shelter to made of Moon-processed materials; **2** Door to other cabin; **3** passage to other shells; **4** Fold down beds; **5** storage space **6** Slide out chairs; **7** Other cabin also served by **8** Twin-sided works core;**9** Fold out table for eating, study, work; **10** Swing out lamp.

© Dan Moynahan

Asteroid Types

from Stephen L. Gillett < gillett@seismo.unr.edu >

[Stephen L. Gillett (cf. "Lunar Ores" MMM #22 p2) now of Carson City, Nevada, sends the following correction to the impression we gave in our reply to the 1st "Colonist's I.Q. Quiz" question in our April "Asteroid Special" - MMM # 22]

It looks as though metallic and stony asteroids are derived from the breakup of small differentiated bodies, which initially heated up enough to mostly melt, thereby separating into a metallic core and silicate mantle. Then over geologic time, most such bodies were broken up by subsequent impact (see, e.g., Sonett & Reynolds; Scott; both in Gehrels [ref. below], 1979). (Vesta may be a survivor!

Although such small bodies could not differentiate now, through not having enough sources of internal heat (i.e., too little natural radioactive elements), at the formation of the Solar System, sources of heat probably did exist: short-lived radioactive elements which are now extinct. The most popular candidate is Aluminum-26, a suggestion that like so many others--goes back to Harold Urey. Al-26 has a half-life of about 0.5 million years and releases a relatively large amount of energy on decay. Also, Mg-26, its daughter product, has been found in aluminum minerals in the meteorite Allende.

In fact, there probably are metallic asteroids, pieces of the core material broken out from such early differentiated bodies; they are probably spectroscopic type M amounting to a few percent of the total (Zellner, in Gehrals, '79).

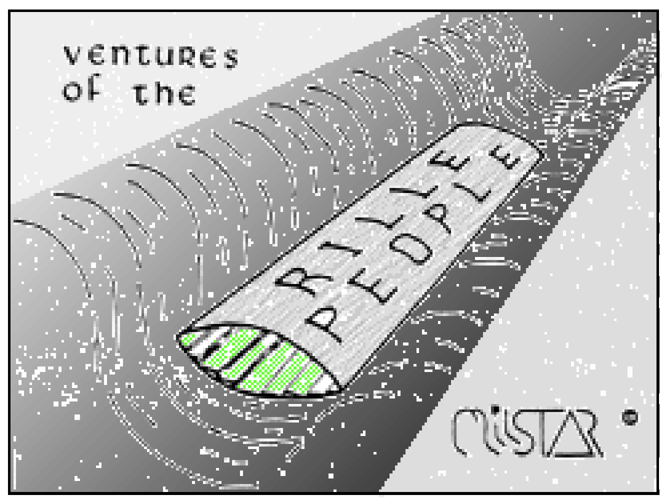
Other evidence that the asteroids were never gathered together in a single body is geochemical, from meteorites: some, especially the carbonaceous ones, are low-temperature mechanical mixtures of phases far out of equilibriun, which would be rapidly destroyed by even modest heating, as would result from being incorporated in a larger body. Additionally, the isotopic "clocks" in meteorites all yield ages on the order of that of the Solar System. These "clocks" result from the accumulation of daughter elements from the decay of natural, long-lived radioactive isotopes, and again, it takes little heating to have the daughter elements diffuse away and thus reset the clock.

I would also recommend to MMM readers the collection from which the paper cited above comes: **Asteroids** edited by T. Gehrels, University of Arizona Press, 1979. It is technical, but although getting a bit old is still an excellent asteroid sourcebook. It's one of a number of highly recommended technical volumes on planetary science put out by University of Arizona Press. **<SLG>**

Moon Miners' Manifesto
#29 - October 1989

Continuing our Report on PRINZTON

a 2-tier 3-village rille-bottom settlement for 3,000 - 5,000 persons



Part IV: VILLAGE RESIDENTIAL AREAS

Peter Kokh, Myles Mullikin & Louise Rachel

A. MODULAR HOUSING

Prinzton would be quite unlike any previous Lunar outpost or settlement. Gone will be the pressure-hull habitats separately covered with meters of shielding soil, the early form of burrow-warren life that will have become synonymous with Lunar subsistence, fulfilling the unanimous prediction. In such accommodations to the Lunar facts of life, there will be the starkest of differences between "indoors" and "outdoors", life and death.

In contrast, Prinzton is constructed within macro-sized and communally-shared pressure envelopes = the sealed rille floor and side-slopes capped with catenary vaults and end-walls. Such a scheme introduces an ample "middoors" environment, open space with generous picture postcard vistas and "shirtsleeve" freedom for getting about, for recreation, and for arranging homes and other buildings that do not need to be each pressure-tight. This will allow construction methods more reminiscent of back-home.

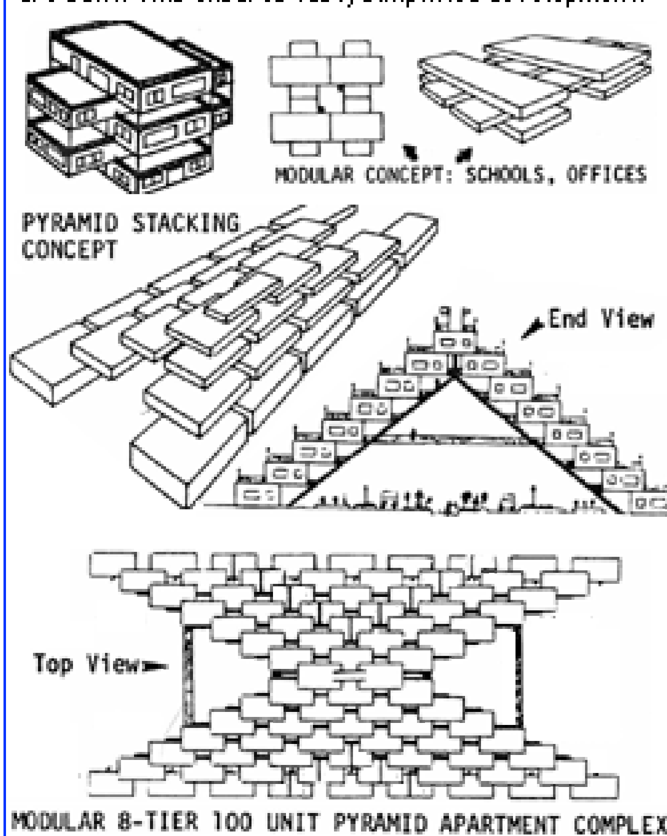
Yet there are important differences between building beneath Earth's starry skies and building under Prinzton's artificial sky-vaults.

1. Lunar gravity is l/6th Earth-normal or "sixthweight". This allows lighter construction for multistory structures, and freer use of cantilever techniques.
2. Building materials commonplace to us may be unavailable: wood, vinyl and other synthetics, some metals. Concrete may well be expensive if economically recoverable Lunar polar ice deposits are not found by Lunar Prospector or other polar orbiters.
3. There'll be a premium on early occupancy. This means that building shells must not be labor-intensive and must be erectable by fast and simple methods. Once occupied, they can be given fresh distinguishing exterior and interior treatments at leisure. Thus a certain look-alike cookie-cutter appearance is to be expected, with personalizing makeovers coming in due time.
4. The very small labor market, not only in contrast to our Earthside experience but in comparison with Space Colony expectation, will work to minimize initial options. "Modularity" will be at a very unsophisticated gross level, especially at the outset.

We had to take all these things into consideration in developing Town Plans for the three Prinzton villages. The first would have to be as simple as possible yet with interesting and attractive features. The plans for the second and third of the villages should illustrate increased sophistication that the growing labor pool and increased industrial diversification will allow.

(1) EASTVALE The plan for the first village, was conceived by Peter Kokh. He chose a simple street plan with a closed loop boulevard, portions of which boast median canals, and 200 individual home sites, 2 100-unit apartment complexes, schools, offices, and other buildings all using a version of the same basic module.

The determining idea behind the EASTVALE Plan is that module shells would be cast in a Rille top factory (at high temperature with the need for concentrated solar heat) probably of glass-glass composites (Glax*) of minimally refined formulation. With openings ready for fitting with standard window and door units, and with the interior surfaces ready for snap-in electrical service, each 1150 sq. ft. unit would be brought down the rille slope in a pressurized cargo elevator (whose dimensions determine module size) to the central freight-transit corridor along the rille bottom. Next they'd move into the village for essential outfitting at a central plant, and then to the home-site etc. for erection and immediate occupancy.



Everything in EASTVALE is Modular

From one basic module, 7.5x15x3.75 m., built in a rille top factory and brought down the cargo elevator, all homes, offices, schools, and apartment complexes are built. This ensures fast, simplified development.

All other finishing would be done at leisure: surface treatments, interior walls, furnishings, etc. Large landscaping trays would be similarly designed to singly, or jigsaw-like, stack neatly in the same cargo elevator.

These restrictions offer a design challenge. Yet interesting combinations are possible via varied module-stacking methods. Opposite, are some illustrations.

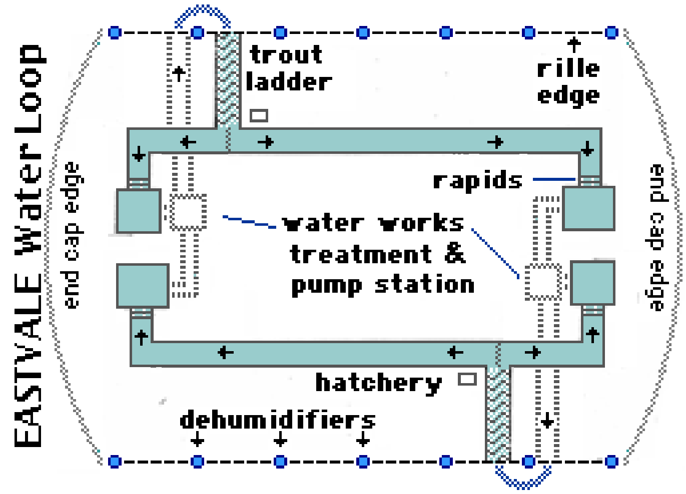
A dull and drab newborn village will slowly transform itself into a pleasant place to live. Homes could be several tiers high as families purchase and stack additional units crisscross on top of one another as the original "issue flat" is outgrown. Many such starter flats may be turned into home enterprise shops, as the growing family moves to new quarters above.

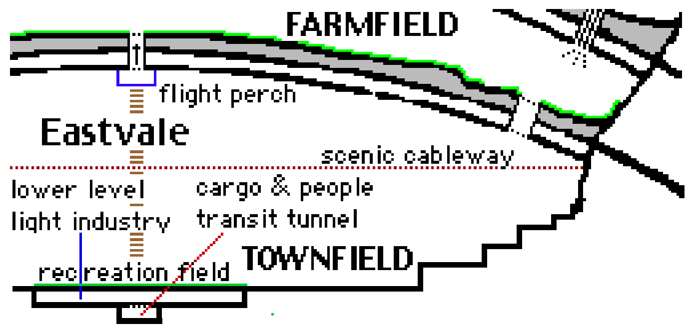
The original grays of crude glax surfaces will soon be hidden under glazes and whitewashes and other surface treatments: tiles, bricks, shutters and panels. Original balcony railing designs will add distinction. There will be an ever-fresh look to EASTVALE townscapes. The need to personalize and individualize will be a strong incentive for new settler enterprises (at first, spare-time endeavors, as everyone is needed to provide essentials).

KEY Below: ⌸ transit tunnel station

200 individual homesites 25x 25m

Cath., Prot. churches, Mosque, Synagog

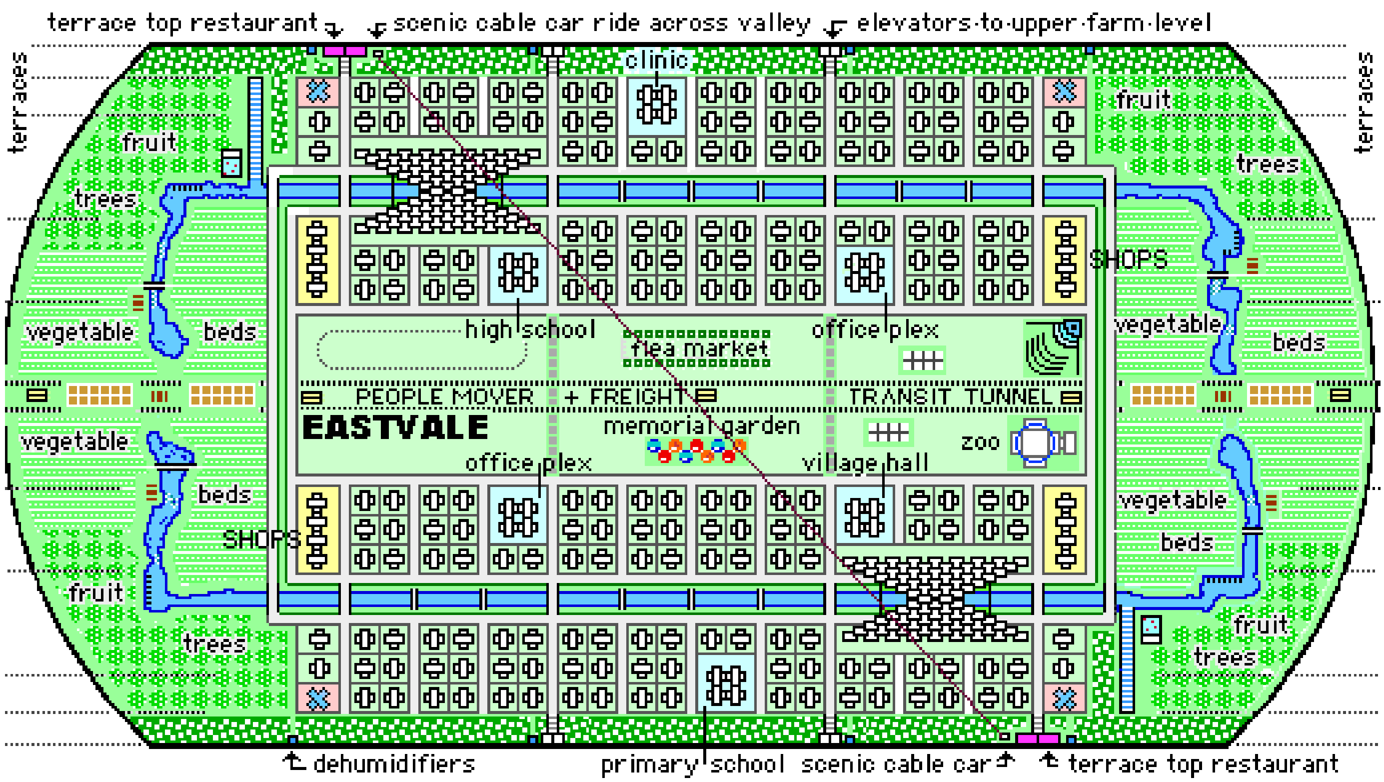




Under the surface Recreation Area level

cotton fabric spin + weave	1	2	3	building panel/module add doors+windows etc.				
4	5	6	7	8	9	10	11	glass composite furniture shop

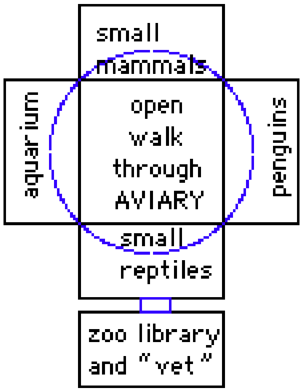
1 basic apparel - 2 u-sew/ u-dye - 3 fiberglass fabrics
4 inorganic recycling - 5 carts/bikes - 6 wrought iron
7 glass - 8 stained glass - 9 ceramics - 10 repair shop



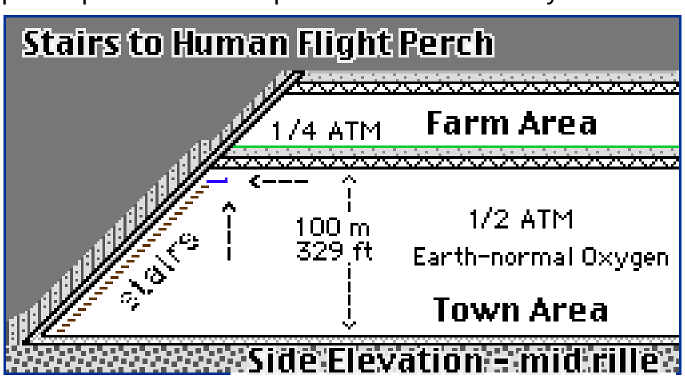
Industries involving heat and vibration and any potential biospheric contaminants are situated on top rille shoulders.

EASTVALE's other amenities. A scenic cableway crosses the townfield valley from the NW upper corner to the SE upper corner [see Eastvale Village Plan on page above]

It also boasts a small (just seven standard modules) animal zoo and aviary in a corner of the central green space recreation area. It is vital that Lunan children grow up with first hand awareness of the animal life that shares our home planet with us. This modest facility would be enough to house a token selection of easy to care for feathered, furry, scaly critters. And some that could be brought out to pet!



There is also a stairway hugging the sloping underside of one of the end caps leading to a perch from which young and old can try their arm-mounted wings at human flight, an age-old dream never realized on Earth because of its high gravity. See the partial cross-section elevation at the top of this page. Here is how the stair way and perch looks from the side.It would be quite a walk up in Earth gravity, but not on the Moon . Many a pioneer will make the climb just for the view, and yes, perhaps to work up the nerve to fly!



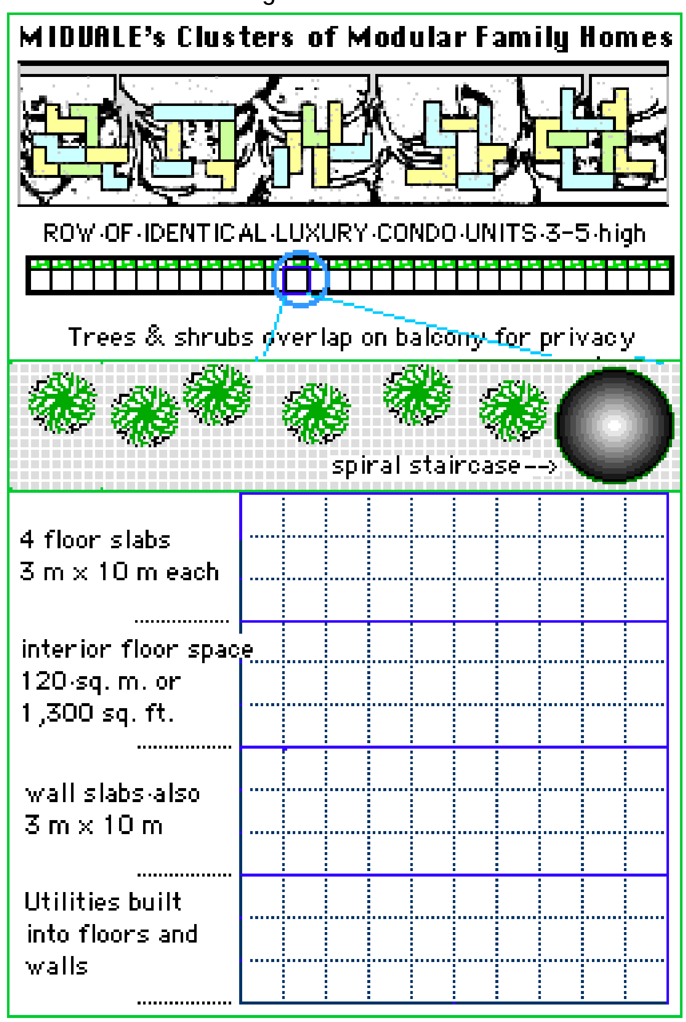
(3) MIDVALE: Village # 2

design by Myles M. Mullikin

Mullikin realized that by the time construction of village #2 began, pioneers would be ready for both more diversity and more luxury in housing. This would mean diversifying industry and food production as well. He also realized that #2 would be ideally suited to include the 24 hour metro functions of service and recreation. Eastvale would be 8 hrs ahead, Westvale 8 hrs behind Midvale, with all the factories running around the clock. So Westvale is divided into two districts. The Metro in one half, the Village in the other half.

The residential area features neat subdivisions of cluster homes, aparment blocks for young couples, luxury townhomes, even a few high terrace mansions. shows a quantum leap in sophisticated modularity. As Prinzton grows, there will be more people to do more things. More individuals will serve the discretionary consumer market their principal occupation.

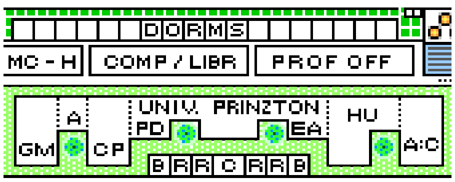
The all-in-one habitat unit has been abandoned as the basis for construction. It has been replaced with modular floor slabs, wall panels and other elements that can be fitted together in a greater variety of home designs with substantially greater architectural freedom from the outset. Again, high temperature casting is done on the rille top, but now assembly is finished within the village industrial park. Early occupancy is still the driver, but in a less urgent manner.



The residential district includes homes for Prinzton's more affluent individuals and their families. Three story, sloe hugging mansions are included. Illustration of Midvale Town Plan below.

The University of Prinzton

Small but vital, the University of Prinzton in MIDVALE will have enterprise formation and assistance as major functions. Concentrating on research and development of 'Moon-appropriate' materials, methods and processes, and marketable applications, the university will further the growth of both the export and the domestic economies. The health of the people will also be in its care. These missions will make the UOP the lead agency in advancing Settlers' ever more thorough acculturation to their adopted world.



KEY: Dorms for students from elsewhere on the Moon. MC-H - Medical Cntr/Hospital Computer Cntr/Library. Professional Offices U. of Prinzton Schools: Geology & Mining, Astronomy, Chemical Processing, Product Development & Enterprise Assistance, Humanities, Arts/Crafts

Twenty Four Hour conveniences:
B=Bar, R=Restaurant, C=Cinema

A "Downtown" Metro District for Prinzton

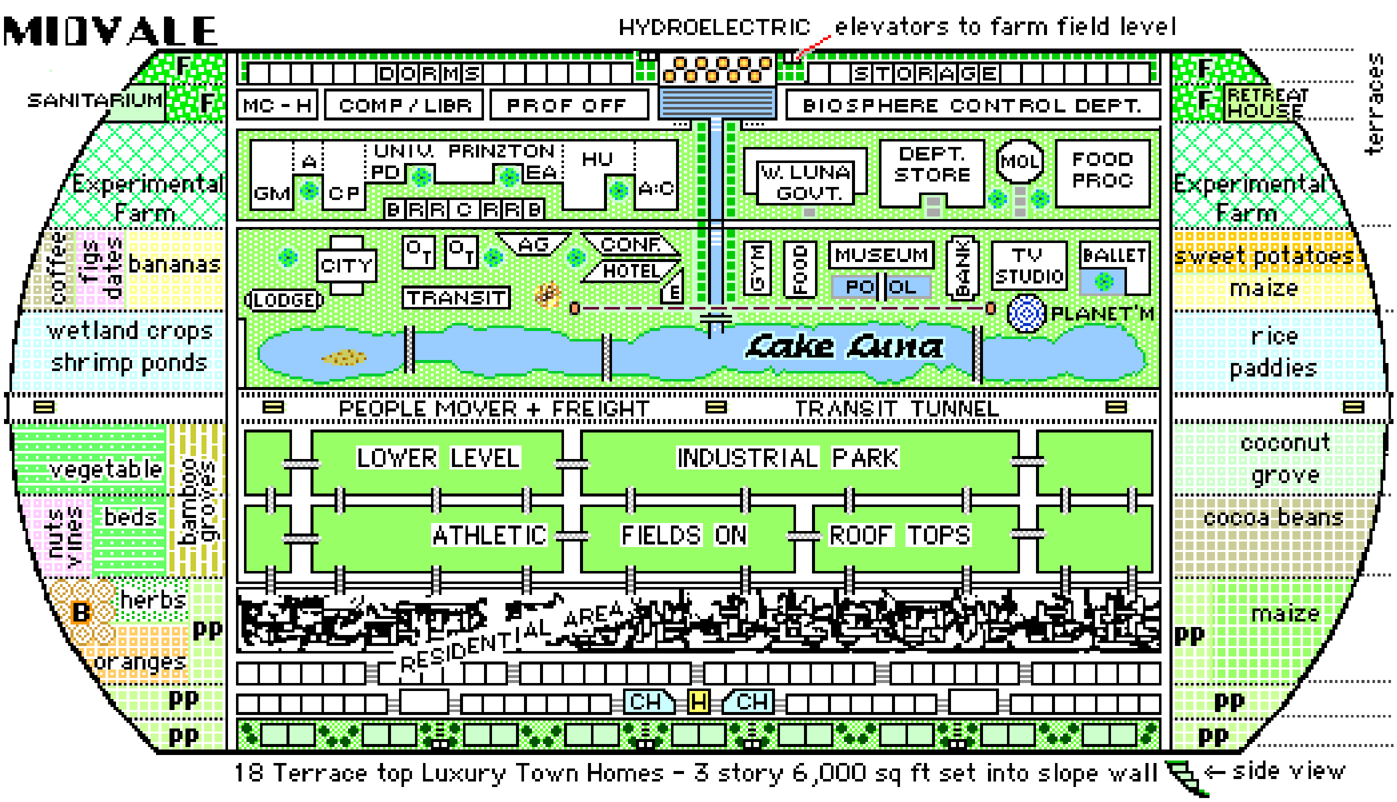
MIDVALE's business district serves as Prinzton's downtown. And more than likely, Prinzton will serve as the metropolitan center for a number of outlying smaller mining settlements in this whole general area of the Moon. This will all work to make the Midvale "Metro" District a much livelier place than one would otherwise suspect from its size.

A "Lake" and a series of water cascades and waterfalls flowing out of a hydro-electric power plant? On Luna?

Lake Luna itself is but a shallow lagoon, but below it is a major reservoir for the hydroelectric system. Overflow from the Lake goes into this reservoir. During the two weeks of dayspan, excess solar power is used to pump water reserves up to holding tanks up on the rille shoulder. During the two week nightspan, this water is allowed to flow down the rille slope to generators on the top terrace of the Midvale Town Field.

So the Hydroelectric system involves both a closed loop and a very large head. The reserves held on the rille top have as much potential energy as the water feeding Niagara Falls, even in the low gravity.

How the Hydroelectric Loop works will be the subject of a follow-on article in this series. "Putting water reserves to work" is a primary design goal.



(3) WESTVALE: Village # 3

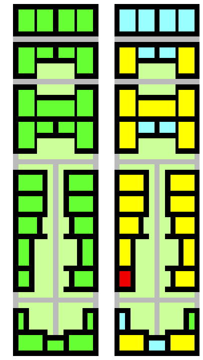
design by Louise Rachel (Quigby)

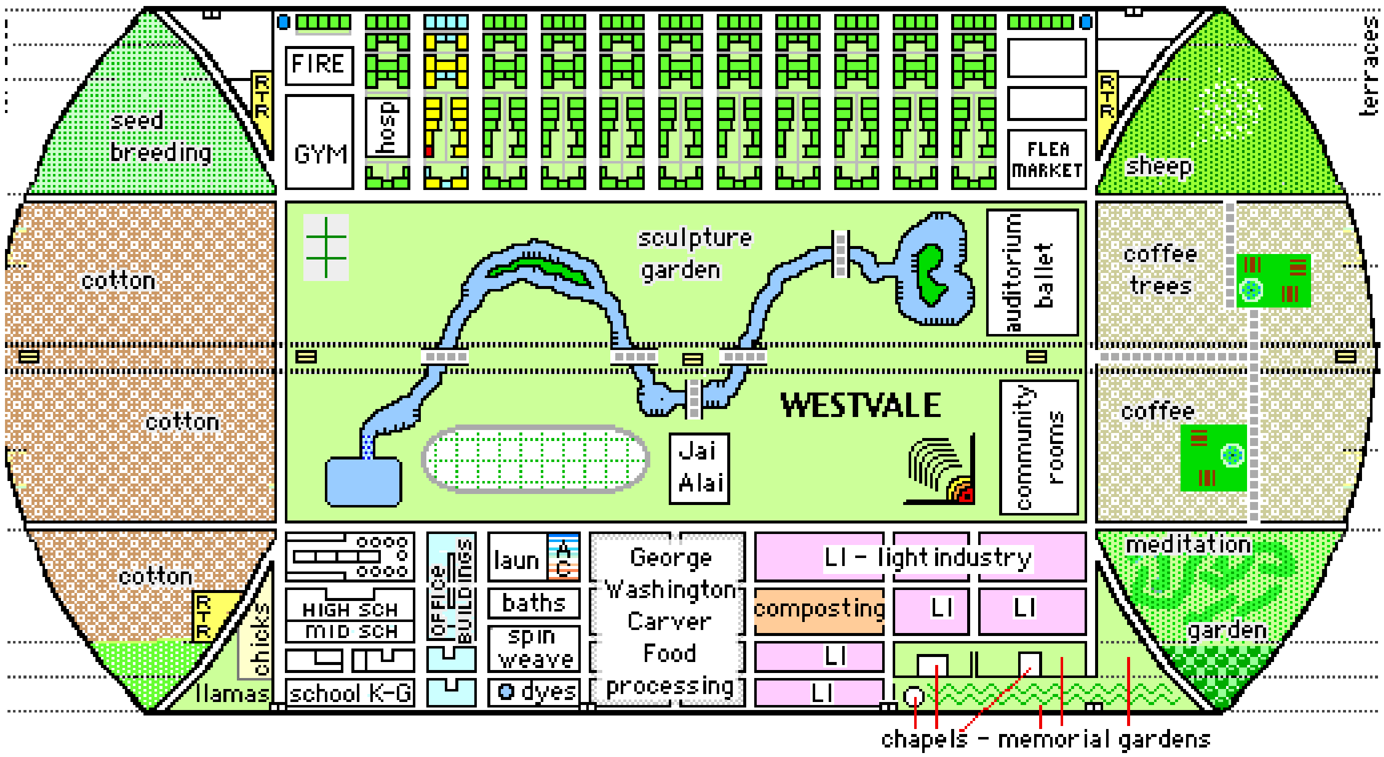
Similar construction systems would be employed in buidling Westvale. But the designer specifies a single neighborhood to one side of a spacious village Commons. This residential neighborhood integrates several housing types around terraced and lushly landscaped courtyards with apartments dominating the uppermost terrace.

KEY to housing clusters:

- apartments
- family units
- community room

Note units on lower residential terrace are grouped around a commons courtyard.





In WESTVALE, there will be ample provision of communal space for enterprise nourishment. By the time such space becomes available, some of the infant enterprises nourished in Eastvale might be ready to graduate to the more spacious quarters and to quantity production techniques. 'Make-overs' by the mushrooming cottage-industry-based enterprises will greet return visitors to Prinzton with much that is new and interesting.

Farming based industries

With the construction of this third village and its accompanying farmfield, agricultural diversity has matured. The designer calls for industries based on agricultural byproducts, thus the illusion to George Washington Carver who patented over a hundred products based on peanut shells and peanut raising waste biomass. Composting will receive more attention. The village will also raise cotton and coffee, and introduce sheep.

B. The Role of Cottage industries:

by Peter Kokh

As we have already mentioned, the desire to express one's own personality in home and building external appearance will be a wellspring of settler enterprise starts. Equally important, will be the need to provide much greater variety of interior furniture and furnishings, clothing apparel and accessories, etc. than the standardized issue items that may be the only goods available on a mass-produced basis. However well-designed basic items are, the quest for personal variety will surge to the fore. Creative persons will use their spare-time and spare home-space to fashion wares and wears to sell or trade to one another in village markets. The rise of cottage industry might be encouraged by income and sales tax exemptions.

Gifted artisans and craftsmen will find ready acceptance of their goods. No department stores or import specialty shops will offer them competition. Their prestige in the community will be first rank, as such frontier settlements give birth to the most vigorous renaissance in arts and crafts humanity has yet seen. [See “Moon Mall” in MMM #2, MMM Clasics I]

EASTVALE's Furniture Plant will be kept busy producing simple utilitarian items. Ready-to-finish movable interior wall sections will be a must. Another staple might well be "a" glass composite chair, with molded back and bottom in place of cushions, with interlocking sides so that more than one can be combined in love seat or sofa fashion, and with open frame and thoughtfully provided attachment points. Such chairs in single or multiple units, will be ready for use as is. But cottage industries could turn out throws and toss pillows, glaze or stencil decor-ation, and fabric, bead-curtain, metal filigree, stained glass, or glazed tile panel enclosures for the side/back open frames, thus transforming such common "issue" into something special and full of pride.

"Issue" glass composite tables could have a raised top edge to accommodate added glazed tile, stained glass, or other inlay (pressed leaves and flowers under glass?) by cottage artisans. Interior space divi-ders of open, ready to elaborate, frame panels will offer opportunity. Craftsmen of knobs and handles will be needed.

"Issue" table and floor lamps might well be simple constructs of lamp cord, conduit, socket, and bare bulb. Home-based enterprises could turn out ceramic, glass, and metal bases for these lamps, and more elaborate creations of stained glass, wire sculpture, or macramé. Similarly, there will be a strong demand for home-produced lampshades and diffusers.

"Issue" tableware could come either simply salt-glazed or unglazed ready for the creative touch. Distinctive pots for flowers and houseplants will be a 'cottage' staple.

"Issue" apparel might include only cotton underwear and uniform plain work clothing. Until Prinzton's labor force is large enough, cottage industry may have to fill the need for casual and formal wear. Bolts of bleached or unbleached cotton fabrics (broadcloth, muslin, denim, terry, and corduroy) will be transformed by pattern makers and embroiderers, and by makers of appliqués and other accessories. A central U-dye-it facility (to manage the water involved in a closed isolated loop using natural dyestuffs) will be served by makers of tie-dye aids and resist-pattern applicators. Makers of buttons, buckles, sashes, belts and knitwear will thrive.

With all this for Prinztonians to do with spare time, television, that great dissipater, could be limited to the daily news, rare specials, and prerecorded how-to-do-it videos. The alternative, attrac-tive to some, will be contentment with monastery-class "issue".

Possible Lunar Ores

POSSIBLE LUNAR ORES

Stephen L. Gillett, Ph.D.
Dept. of Geology, Maackay School of Mines,
University of Nevada-Reno

Exploitation of lunar resources has usually been thought of as scooping up homogeneous regolith for reaction and shielding mass, and for the extraction of common elements: O-Oxygen, Si-Silicon, Al-Aluminum, Fe-Iron, Ti-Titanium, Ca-Calcium, and Mg-Magnesium. Although it has been noted that the first-order chemical differ-entiation between aluminum-rich highland anorthosite versus iron and titanium enriched mare basalts is worth exploiting, and possible concentrations (of volatile elements) at the lunar poles have received much attention, it has otherwise been the conventional wisdom that lunar ores do not exist.

Important **Lunar-Deficient Elements** (**LDEs**) include metals Mo-Molybdenum, W-Tungsten, V-Vanadium, Ni-Nickel, Nb-Nio-bium, Co-Cobalt) for alloying steel, and Zn-Zinc for alloying Magnesium and Alum-inum, special purpose metals such as Cu-Copper, Pb-Lead, Be-Beryllium, F-Fluorine, Cl-Chlorine for industrial reagents, and other volatiles C-Carbon, H-Hydrogen, N-Nitrogen, P-Phosphorus for life support. Carbonaceous asteroids have been proposed for C, H, N, but LDEs are not generally concentrated in asteroidal material (with the notable exceptions of Ni and Co); many are intrinsically rare elements. It has been assumed that most LDEs will gave to be supplied from Earth or else recovered at great cost from the extremely low concentrations in ordinary lunar and asteroidal rock.

Geochemical considerations suggest that local concentrations of LDEs exist on the Moon. Most important LDEs are geochemically incompatible elements and will tend to become concentrated by chemical fractionation processes [Ed. much as oil separates from water.] Although the Moon lacks the bewildering variety of processes that lead to economic concentrations on Earth, the Moon underwent protracted igneous activity early in its history, and certain magmatic processes can concentrate incompatible elements. Such processes include:

(1) Separation of a magma (molten material beneath the crust) into immiscible liquid phases. Depending on composition, these could be silicate-silicate, silicate-oxide, or licate-sulfide. Immiscible sulfides may be particularly important because many important LDEs (e.g., Mo, Cu, Zn, Pb) are chalcophile [while the roots of this term mean copper-loving, in an esoteric switch, geologists universally use this term to mean sulfur-loving].

(2) Cumulate deposits in layered igneous (lava) intrusions

(3) Concentrations of rare, refractory [high melting point], lithophile [rock-loving] elements (e.g. Be-Berylium, Li-Lithium, Zr-Zirconium) in highly differentiated silicon-rich magmas.

(4) Late-stage, volatile-enriched differentiates, analagous to terrestrial hydrothermal fluids although probably waterless, may concentrate relatively volatile [low melting point] LDEs such as halogens (e.g. chlorine, fluorine) and phosphorous [found in the so-called KREEP{ deposits of K-potassium, Rare Earth Elements, and Phosphorous]

Since lunar ore bodies would be relatively small deposits, exploration on Earth must first consist of defining favorable geologic settings. This can follow geologic mapping of the lunar surface by remote sensing. Remote sensing is feasible because lateral transport [of material native in one locale, to another locale] by impact is inefficient, so that the regolith composition reflects the bedrock beneath,) Examination of low-abundance, "exotic" fraction of lunar regolith, the proportion reflecting remotely derived material, will also be a useful exploration tool, because a compositionally distinct rock type should be easy to recognize if present in very small proportions. SLG

Moon Miners' Manifesto #30 - November 1989

NIMF

Nuclear rocket using Indigenous Martian Fuel

An Enabling Technology for Manned Mars Missions with Global Access in a Single Launch

Robert M. Zubrin
Martin Marietta, Astronautics, Denver, CO

ABSTRACT: This paper presents a preliminary examination of a novel concept for a Mars descent, ascent, and exploratory vehicle. Propulsion is provided by utilizing a nuclear thermal reactor to heat a propellant gas indigenous to Mars to form a high thrust rocket exhaust. Candidate propellants whose performance, materials, compatability, and ease of acquisition are examined include carbon dioxide, water, methane, nitrogen, carbon monoxide, and argon. Ballistic and winged supersonic vehicle configurations are discussed. It is shown that the use of this method of propulsion potentially offers high payoff to a manned Mars mission both by sharply reducing the initial mission mass required in low Earth orbit, and by providing Mars explorers with greatly enhanced mobility in traveling about the planet through the use of a vehicle that can refuel itself each time it lands. utilizing the nuclear landing craft in combination with a hydrogen fueled nuclear thermal interplanetary vehicle and a heavy lift booster, it is possible to achieve a manned Mars mission in one launch.

INTRODUCTION: Interplanetary travel and colonization can be greatly facilitated if indigenous propellants can be used in place of those transported from Earth. Nuclear thermal rockets, which use a solid core fission reactor to heat a gaseous propellant, and which were successfully developed during the 1960s under the ROVER/NERVA programs as hydrogen fueled interplanetary transfer vehicles, offer significant promise in this regard, since, in principle, any gas at all can be made to perform to some extent. In this paper we present a preliminary examination of the potential implementation of such a concept in the context of manned Mars missions. The vehicle in question we term a NIMF: Nuclear rocket using Indigenous Martian Fuel.

[Body of Paper Condensed by MMM Editor]

Candidate Martian Propellants

The atmosphere of Mars consists of
95.0% carbon dioxide [CO2]
2.7% nitrogen [N]
1.6% argon [A]

all of which are candidate fuels for NIMF. Water could also be used after harvesting ice or permafrost. Carbon monoxide [CO] and methane [CH4] can be produced from the above atmospheric gases by processing.

Table 1: Ideal Specific Impulse of Martian Propellants

	Temp °K	CO2	H2O	CH4	CO/N2	A
**	2800	283	370	606	253	165
	3000	310	393	625	264	172
*	3200	337	418	644	274	178
	3500	381	458	671	289	187

NB.** 2800 °K = safe operating temperature per extensive NERVA testing
* 3200 °K may eventually be attainable

Carbon Dioxide - composing 95% of the Martian atmosphere, can be obtained by pumping the air into a tank. At a typical ambient temperature of -40 °C, CO2 liquifies at 10 ATM for an energy cost of just 84 kW hrs per metric ton. A NIMF engine produces over 1000 MW (thermal). If an electrical capacity of 1 MWe is built in as well, then the 2800 K, 40 metric ton, NIMF would be able to fuel itself for a flight into a high orbit in less than 14 hours! Liquid CO2 has a density of 1.16 times that of water and is eminently storable under Martian conditions.

Since CO2 is so readily acquired, it is a convenient fuel for multiple suborbital hops, allowing a Mars exploration mission to visit many sites (either as a ballistic hopper or as a supersonic winged aircraft. - Figures 1 & 2).

One drawback is that CO2 (and water) would oxidize carbide elements at the high temperatures involved. Instead, high temperature oxide elements, possibly coated uranium-thorium oxide, must be used, and such elements would probably be incompatible with the high Isp hydorgen fuel ideal for interplanetary usage.

Water: In the form of permafrost ice, water is commonly expected to be abundant, but it will require an operation of some complexity to harvest it. Once a Martian base is established, locally mined water could function as a near ideal fuel for both Earth return, near Mars, and beyond Mars operations. If a base on Phobos is used for a point of departure, a 3000 °K water propelled NIMF could fly to Earth, aerobrake into a loosely bound orbit, and return to Mars without refueling!

Methane: Per the table above, methane would be an excellent high Isp [specific impulse] fuel. It could be pro-duced and stored under refrigeration at advanced surface stations (not suitable for early use or needs). Moreover, it is compatible with conventional NERVA carbide elements. An unresolved problem is that methane would dissociate at the high temperatures involved with free carbons causing coking problems. Experimentation is needed.

Nitrogen, carbon monoxide, and argon [see the table] are inferior to the much more readily available carbon dioxide. Further, they require about a hundred times as much energy to produce. However, they have the advantage of not reacting chemically with fuel or cladding materials compatible with hydrogen. Thus the same reactor which uses carbon monoxide for ascent to orbit could also use hydrogen with 950 Isp for interplanetary transfers.

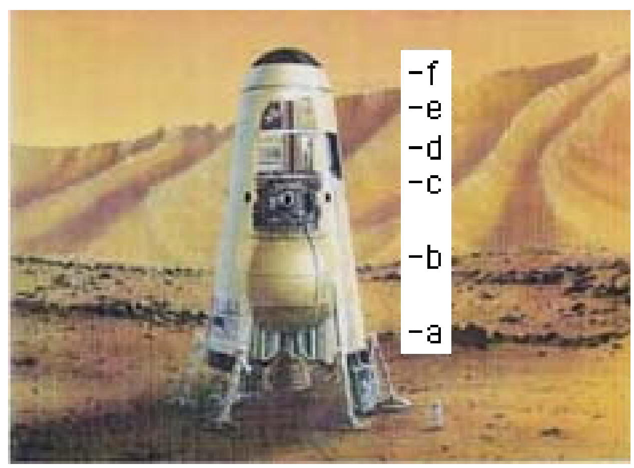


Figure 1: A NIMF ballistic vehicle on Mars. (by Martin Marietta artist Robert Murray]

a. Nuclear engine surrounded by a coaxial fuel tank (when full, augments the solid lithium/tungsten shadow shield with liquid CO2)
b. main spherical fuel tank
c. Machine deck with CO2 intake pumps.
d. Habitation deck.
e. Command deck.
f. Parachute (several) compartment.

Nb. The NIMF's fuselage acts as an aero-brake, with a lift/drag approaching unity.

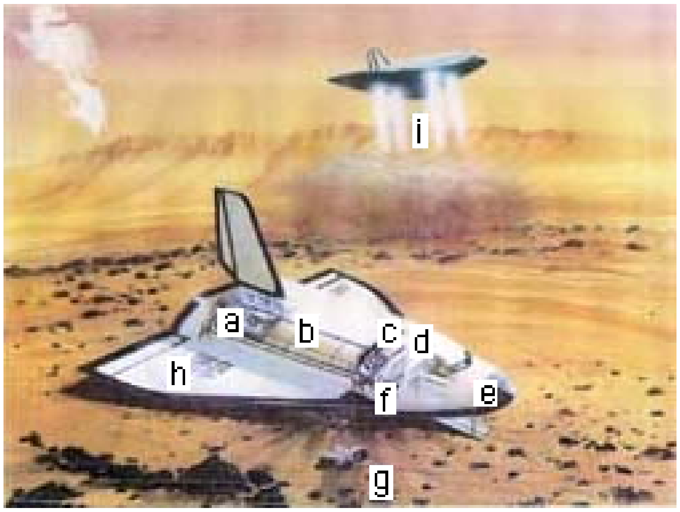


Figure 2: Winged NIMF rocketplane on Mars. (courtesy free lance artist Jeff Danelek)

a. Nuclear engine surrounded by coaxial four-pi liquid shield
b. The main tank forward of the reactor.
c. Machine compartment
d. Habitation compartment
e. Control deck.
f. Forward storage area with ramp
g. Electric rover charged by NIMF reactor
h. Delta shuttle-like wings for supersonic flight with lift/drag of 4 at Mach 4
i. 4 VTOL rockets on underside for Harrier-like landings/ascents from/to Mach 1

A NABBED NARS NUSSION IN A SINGLE LAUNCH

Since the days of the Apollo program, NASA's thinking about manned planetary landings has been dominated by by approaches based on an orbiting mothership containing long term living quarters and a small landing craft, a fraction of which manages to ascend to orbit after a stay on the surface. With the advent of NIMF, such an approach is no longer necessary. In fact, since any mass landed upon Mars can be lifted back to orbit using readily available indigenous propellant, it becomes advantageous to abandon the concept of the orbiting mothership altogether, and instead land the entire spacecraft living quarters on the planet's surface. That is, NIMF and interplanetary vessel are one.

Three alternative mission scenarios were examined. In each case, a 40 metric ton NIMF with a 3 person crew departs from a 300 km LEO orbit on a minimum energy trajectory to Mars, lands on Mars, hops around visiting various sites, ultimately returns to Earth via Hohmann transfer orbit.

Scenario I uses an orbital transfer vehicle (OTV) to propel NIMF out of LEO, and which is then expended. This is the cheapest option in terms of total fuel use.

In the other two scenarios, the OTV accompanies NIMF to Mars and is stored in Mars orbit for the joint return. In Scenario 2 both aerobrake at Mars, saving fuel while in Scenario 3 the NERVA-OTV brakes via a retrofire to keep it out of the Martian atmosphere. In either variation, artificial gravity could be provided for the long interplanetary trips out and back by spining the pair at opposite ends of a tether.

NIMF MANNED MARS MISSIONS: 3 SCENARIOS

(metric tons)	Scen.1	Scen.2	Scen.3
Mission Mass	73	100	145
Expended Mass	33	53	100

There are numberous mission architectures where an initial manned Mars Mission can be accomplished with a single launch of the STS-Z (125 MT to LEO) or ALS (100 MT to LEO) or even by a single Shuttle-C (80 MT to LEO). Furthermore, repeat missions (craft already in space, needing only refueling and reprovisioning) can be supported by a single shuttle, Titan IV upgrade, or STS-C launch. This contrasts with current NASA plans which would require from 700-1000 metric tons of propellant per mission, 6 or more STS-Z launches! Yet despite their enormous cost and complexity, such mission plans leave the explorers relatively impotent to accomplish much in the way of either exploration or development, as their cryogenic landing vehicle will necessarily restrict their visits to ne site, and they lack a substantial source of electric or thermal power i.e. little potential for human exploration of the Red Planet and none at all for sustaining a human presence there. NIMF will allow ready, repeated, and inexpensive access to Mars, opneing up a new world to humans.

MERITS OF NIMF VS CHEMICAL (CO+O2) HOPPERS

In some respects, these two candidates for getting around Mars (Global Access) are equal. Both obtain a specific impulse in the 280-290 range. While neither engine is a developed technology today, the principles underlying both are well understood, and either could be developed given the appropriate development funds.

However, that's where the equivalence with the chemical option ends. The energy cost for producing CO and O2 from the atmosphere is more than one hundred times that for simply liquefying the given CO2. Worse yet for the chemical hopper, we not only have to pay an exorbitant premium for the fuel, but we have to pay for a ground-based nuclear reactor and a significant chemical engineering plant. That's a lot of infrastructure that NIMF doesn't need. The corresponding features are built into NIMF. If we go with the chemical option, global access will be delayed possibly for years, until the needed development is in place. With NIMF, such global access is an immediate capability.

Since NIMF can refuel itself for return trips, it can go as far one way as its fuel will allow, landing empty. In contrast, the chemical hopper must carry fuel for the return *and* extra first leg fuel to bring the return fuel along. By the same token, we can afford to build NIMF heavier, with a stronger frame that can carry more instruments and supplies, capable of extended forays.

The chemical hopper must be on target on its return trips, pay attention to boil-off, outgassing, and other potentially explosive and toxic leakage of its cryogenic fuels. Immune to all this, NIMF can recharge the fuel cells on land rovers it carries, not so the chemical hopper.

Highly versatile non-ballistic supersonic winged aircraft configurations are possible for NIMF which is less weight restricted. Because the NIMF propellant is the atmosphere itself, in-flight propellant acquisition systems are possible - not so for the chemical vehicle.

What about safety? NIMF carries a nuclear reactor (however 5 orders of magnitude less radioactive than a power reactor, and not capable of meltdown). This small radioactive inventory represents a small hazard compared to that presented by the chemical alternative to NIMF, which will be virtually a flying bomb, a lightly built structure filled to the gills with toxic gas and chemical high explosives.

OTHER EXOTIC MISSIONS FOR NIMF ALONE

- A winged automated NIMF condensing its CO2 from the air, could carry out a **Venus surface sample return**, collecting ground samples and low level aerial reconnaissance from every part of the planet before returning to orbit.
- A methane propelled NIMF could use **Titan as a base for repeat sallies to Saturn's moons**, returning to Earth with ground samples and low level observations from each one.
- A water fueled NIMF could **explore the Jovian system** from Callisto, Ganymede, and Europa.
- Water fueled NIMFs refueling on Ceres, the Trojans, even comets, could explore the Asteroid Belt, and the entire system including Pluto as well as comet sample returns. - [**RZ**/pk]

WANTED

by Peter Kokh

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

- Mars Expedition Personnel Office
- Mars Training Camp • Spitzbergen

For as long as the era of chemical rockets lasts, interplanetary journeys to Mars or the asteroids, will be long tedious affairs that will be very trying for the kind of people ideally suited for the kind of life that awaits them at their destinations. This presents us with a choice. We can either look for persons with such chimeric personality combinations as suggested above who will perform reasonably well under such diametrically opposite circumstances, *or* we can start now to plan ways to structure the times of transit to better fit the personality traits of those best cut out for the exploratory and/or rugged pioneer life on the untamed worlds of their destination.

The path of least effort, and a temptation to mission planners, is the former. Transit times will be filled with make-work: solar-wind measurements and other astronomical chores that could either be done just as well from LEO, or if not, by robot probes. To this will be added routine periods of exercise and other monastic treats. Meanwhile, people better suited for the planetary surface stay itself, will be bypassed if they evidence any signs of being less content than pigs in a mud hole by such a diet of time-whittling.

We need to take a creative look at

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

The opportunities for damping these feelings with engrossing and meaningful activities are also diverse. In the article "M.U.S./c.l.e." [MMM #18, Sep. '88] we suggested that equipment manufactured on Earth for use on the Martian surface be disassembled (all parts tested and checked individual and in test assembly) to be put together in a Big Dumb Volume hold manufactured for the expedition in Lunar Outposts. The crew would be highly motivated to put everything together right. This opportunity will predictably be seen as risky business by some who may favor keeping Mars-bound crews busy performing safer make-work.

Surface expedition concluded, the crew would be similarly motivated to do preliminary chemical and physical analysis of samples being returned to Earth, along with some building materials processing experiments. NASA, however, may forbid them to touch the samples, not trusting them to handle the precious cargo and possibly invalidate intended research by more expert investigators in better equipped Earthside labs.

In both cases, there is probably a point of compromise between NASA's natural paternalistic prudence and the not unimportant needs of the explorers-en-route. For example, ultra-critical equipment can be shipped preassembled, with less sensitive equipment and backup equipment shipped "KD" (knocked-down) for assembly en route.

For the Earth-return, a similar division could be made. Surface samples could be separated into two quota portions, those held safe and untouched for labs on Earth/ LEO, and those on which preliminary analysis and experimentation can proceed en route; trained geologists, chemists, and other scientists will be essential to the crew. To deny them "first rights" can only sow and nourish a festering resentment. Such avoidable psych-ological compost heaps should not be dis-counted as threats to the overall success of the mission.

In the overall spirit and atmosphere aboard the return crew vessel is positive, there will be other time-filling things to do. Debriefings and reports while experiences are fresh can be followed by round table discussions of how the success of a follow-up mission could be enhanced (new equipment, tools, lap facilities, housing etc.; better training; additional talents represented in the crew mix, etc.) Sensory and other impressions can be set to canvas or disk by those on board of artistic, poetic, or philosophical bent.

So much for generalities. Undetermined at this time, but absolutely relevant to the matter we are considering, is whether the voyagers will enjoy the amenities or artificial gravity for the long coast out and back. One gets the feeling that provision of at least fractional weight poses engineering challenges that neither Intercosmos nor NASA are eager to tackle. So what if the astronauts or cosmonauts can survive such long periods of zero-G without irreparable harm! The uncllengable reality that the crew of a zero-G ship will arrive at Mars in a physical shape unequal to the demanding tasks at hand in the very limited time frame provided, should be more than enough to convince mission planners to err on the side of patience. One wonders whom they are kidding!

Marsweight, 38% Earth-normal, can be provided by a simple tether arrangement with crew pods at one end and equipment not needed before arrival at the other. Artificial gravity can also be provided more elaborately by a fixed structure, for example by a conjoining for the Marsbound craft as in the Case for Mars I studies.

Experiments with tether-provided artificial gravity could begin soon using the Shuttle and an External Tank brought to orbit with it. We have yet to do an EVA in an artificial gravity environment! An astronaut would have to remain tethered and would share the angular momentum that obtained at the exit lock. It would be tricky stuff at first, fraught with perils that could nonetheless become routine, even as driving in heavy traffic or flying in formation. Appropri-ate maneuvers and cautious could become second nature. There will be mis-moves but careful provision could minimize serious accidents.

The point to be made here is that, to NASA's abject horror, no doubt, there is a very real opportunity for totally new tethered-EVA sports outside rotating structures. By shortening a tether to the hub, one would advance on the structure; by paying it out one would fall behind - simple conservation of angular momentum. Using such maneuvers in tag matches might be risky, but rally-type events tin which one faced the clock, one at a time, to land first on a forward perch or tag ring, then on one to the rear, before returning 'home', all b manipulating the effective length of the tether, could provide healthy, adrenalin-racing sport. This could be welcome stuff to a crew chosen to be optimally tuned to the pace of activity of the Mars surface part of the expedition. When such sport is embraced, either on the sly or with reluctant official consent, we'll have come a long way towards making the spacelanes home. [PK]

MARS CALENDAR

FI$CAL POSTSCRIPT

[to "Mars Calendar" MMM #19 October 1988]

by Peter Kokh

In the previous article, we suggested that the 668.6 Martian date (24 hr 37 min 23 sec) long orbital period of Mars was an inconveniently long peg on which to hang anniversaries and the rotation of holidays, holy days, and other recurring observances. Halving this period would provide more comfortable 334.3 Mars date ceremonial cycles 343.4 Earth days long. All that would be required would be the introduction of a distinction of terms. The "demi" period described above could be called a "Marscal" or an "Ennium"; the full orbital period, a "Zodian" i.e. once around the Zodiac, or something to that effect.

Reaction to these suggestions was generally positive. But we also heard from Tories (ie. those unable to leave the mother culture behind) who insisted that for practical business reasons, the standard 24 hour Earth day and 365/6 day year would prevail throughout the Solar System, that when the Sun rises or sets on Mars is irrelevant. (We had suggested that Martian Law protect such people, allowing them to hide "Earth-style" calendars under their pillows without fear of search & seizure.)

To fairly address the interests of business in this matter, let's take another look, this time from the vantage point of the business cycle: the Fiscal Year. On Earth, a "fiscal year" is any twelve month period, not necessarily coincident with the calendar year, that provides a convenient accounting cycle for a particular business. By common practice, any business subject to regular busy and slow seasons, closes the books, completing the accounting cycle, at the end of its most active season. Businesses catering primarily to summer tourists might close their fiscal year on Sept. 30th, beginning the next on October 1st. Ski resorts might pick March 31st as the end of their cycle; Department stores January 31st, etc. At any rate, it is the seasons or consumer buying cycles or inventory cycles - the length of the fiscal year on Earth remaining the same - the 365/6 days of the civil calendar.

On Mars, those businesses involving transactions principally among the settler population and whose ups and downs are significantly affected by the passage of the long Martian seasons, will only be able to introduce real accounting regularity (fiscal comparability of one business cycle to the next) by adopting the full 668/9 date length of the Martian "year" or "zodian," with cycle opening and closing dates appropriate to business type.

It is reasonable to expect at least some businesses to fall in this category. But we might also expect services and manufacturing businesses whose ups and downs will be pegged rather to the civil "demi-calendar" of 334/5 Mars dates.

But then what about the Export-Import Houses trading with Earth and the Moon? And what about manufacturers on Mars who depend heavily on Earth/Moon-sourced shipments of parts? Won't they want to use Earth-standard fiscal years?

The answer to that is clearly NO! Until new methods of interplanetary propulsion antiquate the term "launch window", the one overwhelming Fact of Earth/Moon - Mars trade will be their mutual orbital synodic period which determines the frequency of launch windows. And this period coincides with neither terrestrial nor martian years, but averages 780 standard days or 760 Mars dates, some 25.6 months.

In short, business considerations may well lead some Martian enterprises to adopt fiscal cycles other than the 334/5 date civil Calendar we proposed for Mars. But even if Earth UT Time & Date provides a common shipboard reference time throughout the System, *on* Mars, businesses and settlers alike will live, work, and dance to more locally appropriate drums. **<MMMM>**

Segue to the next Volume
f MMM Classics

The Final Installements of the 1989 LRS PRINZTON Design Study for a two-tier, three-village rille-bottom settlement for 3,000-5,000 pioneers, serialized as "The Ventures of the Rille People," will conclude in the next volume of MMM Classics, MMMC #4

So Where is Prinzton, Anyhow?

Prinzton lies in the rille within the red box. The 50 kilometer, 32 mile wide mare-flooded crater Prinz is in the foreground