

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

Moon Miners' Manifesto

www.MMM-MoonMinersManifesto.com

MMM Classic Themes

Lunar Surface Activities



The first "surface activity" on the Moon (Armstrong's 1st step) and the last moments for Cernan and Schmidt, A17

We've come to call the Moon's surface, as a scene of activity, as the "Out-Vac" – yes an allusion to Australia's Outback, as exposed not only to vacuum, but to all the cosmic elements that affect the Moon: cosmic rays, solar flares, and the incessant micrometeorite rain, and the extreme heat of "dayspan" and the extreme cold of "nightspan."

While pioneers will spend most of their time in pressurized environments under a shielding blanket of moondust, some will have to venture out-vac for limited periods to explore and prospect for minerals, to build roads and other outside construction jobs. But people will also travel across the surface in motor-coaches and trains.

There will be shielded arenas left unpressurized so that people can engage in sports that combine low gravity with vacuum, without the risk of radiation exposure and hot-cold extremes. Artists will create sculptures to say "we are here to stay" around entrances to individual homesteads as well as to settlement gates, and along the walkways through "out-vac" nature parks. Of course, many similar works of art will adorn individual homes and public places "inside."

Some will venture out to look for rare rocks, others for road racing, just plain hiking, and more. One way or another, as much as pioneers will have to spend most of their time more fully sheltered, they will nonetheless engage in recreational activities out-vac. And, of course, they will travel between settlements and outposts which will slowly spread the human presence around the globe, an expanse as large as Canada, The United States, Brazil, and China put together. Motor coaches will come first, but as the number of population centers grows, uniquely designed railway tracks and cars will appear.

Not all will be content to live in the growing settlements, on their way to become cities. Small hamlets will appear where there is economic justification for them. Life on the Moon will flower into many kinds of situations, just as on Earth: something for everyone. And there will be National Parks and Monuments. People will visit the sights!

Not to forget the sights in the sky: Earth, of course from Nearside, and the Milky Way in unbelievable glory on the farside. Out-vac activities will do a lot to make the Moon a "world."

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MMM #3 – March 1987

ESSAYS IN "M":
Mare – Maria – Multiple Sites – Mounds

By Peter Kokh < kokhmmm@aol.com >

M is for MARE, PL. MARIA (MAH-ray, MAH-ri-a)

The large dark areas on the Moon, the so-called Lunar Seas, formed three to four billion years ago when most of the large impact basins filled with layers of a very low viscosity lava and cooled. Some such basins on the Farside of the Moon did not fill with lava and are called "Thassaloids" (from the Greek word for sea).

While an initial Lunar Base might be built just about anywhere, once more extensive settlements are built, the maria are clearly preferable. The regolith, the loose surface material, composed of rock fragments and soil, which overlies consolidated bedrock, has a very variable thickness in the highlands, from zero to 30 meters. On the mare, however, the **regolith** has a more uniform depth of about 10 meters, which makes construction easier. While Lunar concrete relying on calcium rich highland soil and **supported** hydrogen will be a lot cheaper for initial base construction than pre-built modules brought from Earth, once a lot of construction is planned, even that method will be too costly. The only way to go is site-extrusion, building the structures from the fused soil on the site itself. Mare soils melt 200C (360F) lower than highland soils and so will require significantly less energy either in fusing rammed soil or in making panels of cast basalt. The melt's lower viscosity will also help in some applications.

The levelness of the mare surface will also be an asset to laying out any extensive settlement. And importantly, the average atomic number and weight of mare soils, as compared to highland soils, makes them preferable for shielding against cosmic rays, etc.

But the best mare sites will be just "offshore" so to speak, so that highland soil, richer in aluminum and calcium, will also be available for manufacturing and processing. Finally, such a site will offer more scenic and recreational interest. [Articles in later MMM issues call for "coastal" sites, in the spirit of this last paragraph.]

M IS FOR MULTIPLE SITES:

One settlement a world does not make! Of course one must start with a single site, and it will be able to serve most of the initial needs. But no site has all the assets. Soils differ not only from highland (or "**terrae**") to mare but also from mare to mare and even within a given mare. Different materials are available to the prospective processor or miner at such sites as crater and rille walls, the central peaks of some large craters, and the so-called dark mantle deposits.

Some polar areas might have **permashade** fields of frozen volatiles like ice and carbon oxides. Some sites will be especially scenic. Locations along the limb between nearside and farside "**librate**": the Earth will alternately be just above and just below the horizon -- anyone want to build the first Lunar Honeymoon Resort? An observatory dedicated to the Great Andromeda Galaxy, M31, could be built in the North, while a similar installation in the south could concentrate on the Magellanic Clouds. Farside would be best for observation of the Milky Way and for giant radio telescopes and SETI searches, etc.

M IS FOR MOUNDS:

The first impression anyone will have of a Lunar Settlement will be that of a complex of mounds, the two-four meter (six-thirteen foot) overburden of Lunar soil used as thermal insulation and cosmic ray shielding. The downward pressure of this much lunar soil per square inch is much less than the upward pressure of the air inside the habitat. So this blanket of soil does not present a stress upon the habitat(s). You can look at this blanket of dust as an analog of the blanket of air which protects you could freeze out Earth's atmosphere, it would provide a light snowy blanket about 15 feet thick. **MMM**

MMM #5 - May 1987

MOON WEATHER

WEATHER ON THE MOON

By Peter Kokh kokhmmm@aol.com

On Earth, the weather forecast often plays a major role in our decisions. Can we go golfing? Fishing? Swimming? Can we go on a picnic or hang out the wash to dry? Do we need an umbrella? Or a shovel? Will it be a good day to paint the house or wash the car? Or are indoor activities in order?

Beyond this, we anxiously watch storm paths. Will the latest hurricane threaten the area where we live? Is there a danger for blizzard, ice-storms, tornados, brushfires, etc?

Finally, without the fickle weather, how would one ever find anything to say to a stranger or acquaintance? On the weather free Moon, will we be at a loss for words, passing one another on the street with eyes averted? Will sports be more closely watched, not because we really enjoy them, but because we need something innocuously trivial to talk about as a social lubricant?

Well, the Lunar environment isn't quite all that cut and dried. First, believe it or not, there will be a slight seasonal difference in the seemingly steady-state indoor Lunar temperature. (Six feet down, insulated from the heat of the sun and the cold of the night, the Lunar soil is a steady -20°C or -4°F , very manageable for the buried habitats and factories and connecting walks, streets, and plazas. Just the heat of life and industrial processes will make up most of the heating needed to provide livability.) There is a difference nonetheless of about 3°F between March and September. This seasonality comes not from polar tilt (only 1.5 degrees) but from the Moon and Earth being 4 million miles closer to the Sun on January 1 than on July 1 with a couple of months lag time in consequent build up and loss of extra heat.

Then there are solar flares. Flare seasons are long and in sync with times of active Sun with a period of about eleven years from peak to peak and quiet flare-free times in between. But in flare season, warnings of particular storms will be on very short notice. Flare storms will not affect indoor or "middoor" (see this month's "Essay on 'M'", below) activities but will affect those who have business on the surface. A network of permanent flare shelters, e.g. at intervals along highways, etc. will probably be built. There will probably be portable or mobile shielding canopies at construction and mining sites. These will probably be in common use anyway, as working under them will require lighter suits that need pressurization but not cooling or as high a degree of micro meteorite protection. Such suits will be more comfortable, more supple, and allow many more accumulative hours of surface activity at reduced cosmic ray exposure.

But there will always be some work done outside the easy range of such protection. For these workers and for travelers, warning times must be maximized. One way to do this would be a set of six solar synchronous satellites. Here I do not mean synchronously interposed between Earth-Moon and Sun, but in an orbit, well within Mercury's, where they each remain in step with the rotating Sun. The Sun's "day" is slightly variable, but an orbit about 16 or 17 million miles out would allow the "Vulcansats" to keep track of potential flare-producing sunspots for the duration of their lifetimes, each satellite watching its own 60 degree wide sector.

Moonquakes are below the threshold of concern and would be felt only by instruments. But meteor showers, especially the predictable ones, will stir protective measures. On Earth, these bits of comet debris burn up in the atmosphere and are harmless beauties. On the Moon they zoom in without visible indication. They just hit, now and then with damage. But what is life, if there is no risk at all?

MMM

ESSAYS IN "M": Middoors – Matchport

By Peter Kokh kokhmmm@aol.com

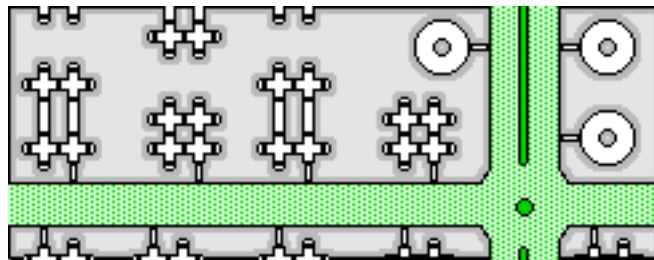
FOREWORD: On the Moon, exiting an airlock in a space suit is something that architecture and engineering will both seek to make as unnecessary as possible. This for two reasons. First the high Lunar vacuum ($10\text{E}-12$ torr daytime facing the solar wind, $10\text{E}-14$ torr nighttime sheltered from the solar wind) is a precious industrial and scientific resource especially in combination with the Moon's substantial gravity. Opening airlocks for exit or entry and purging atmosphere into the vacuum, if done frequently enough, will degrade the vacuum to a point that the solar wind can't restore through its flushing action. Second, the nitrogen used as a buffer gas and biogenic ingredient in the colony's atmospherule must be imported and therefore must be conserved. Making up for preventable losses could well tax the colony's capacity for growth.

M IS FOR MIDDOORS:

On Earth we have been familiar with the distinction between indoors and outdoors for many thousands of years. In the last two decades or so, a new environment, the middoors, has become familiar to most of us in the form of the enclosed, climate-controlled streets and plazas of many a shopping mall. The "landscaped", sunlit central atrium in some new hotel and office buildings offers another kind of model.

In Lunar cities, except to enter and exit those (e.g. industrial) facilities which for safety's sake must keep their air unmixed with that of the city at large, it will be possible to go most anywhere without donning a space suit. Homes, schools, offices, farms, factories, and stores will exit, not to the airless, radiation-swept surface, but to a pressurized, soil-shielded, indirectly sunlit grid of walkways, residential streets, avenues, and parkways, parks, squares, and playgrounds.

While the temperature of traditionally indoor places could easily be maintained at "room comfort" levels, that of the interconnecting middoors of the city could be allowed, through proper design, to register enough solar gain during the course of the long Lunar day (dayspan), and enough radiative loss during the long nocturnal period (nightspace) to fluctuate 10 degrees F on either side, for example from 55-85 degrees F during the course of the month. "The Great Middoors" could be landscaped with plants thriving on this predictable variation. This would be both invigorating and healthy for people, plants, and animals alike, providing a psychologically beneficial monthly rhythm of tempered mini-seasons. Of course the middoors could also be designed to keep a steady temperature. But oh how boring that would be!



Section of a neighborhood: individual homes open onto pressurized "middoor" streets hosting the bulk of the settlement's modular biosphere and vegetation.

M IS FOR MATCHPORT:

To go from one Lunar city to another, or from the city to the space port or other outlying installations, or to transfer from one vehicle to another, all vehicles and city docks or marinas will be equipped with standardized matchports or interlocks. These will probably be of unisex design rather than male-female, and with either able to do the necessary aligning for safety's sake (although there will undoubtedly be protocols). When the two match-ports are aligned and locked (vehicle-vehicle or vehicle-city), the narrow -- hopefully less than 1 cm -- vacuum gap will be slightly over-pressurized allowing port doors to unseal and open easily inward (into vehicle, into city).

Prior to disengagement, the port doors closed, the narrow inter-door gap would first be flushed with pure oxygen and then this would be pumped out (into vehicle, into city) to provide a low grade vacuum which would seal both port doors by internal pressure (vehicle, city) allowing the vehicle to pull back its matchport and depart, with the escape to the outdoors of only a minuscule amount of cheap oxygen -- no precious nitrogen would escape.

There would probably be three common matchport sizes: for personal surface vehicles, for public surface transports, and for cargo rigs. Outside of safety drills held periodically, perhaps most Lunans will live and travel widely about the Moon without ever putting on a spacesuit. It won't be necessary.

MMM

MMM #7 - July 1987

ESSAYS IN "M"
Month or Sunth - Meridian - Metonic Period

By Peter Kokh - kokhmmm@aol.com

M FOR MONTH, OR SUNTH:

Originally, of course, the term "month" meant the span of a full set of four phases of the Moon, e.g. from full moon to full moon, or from new moon to new moon, terms which render the appearance of the Moon to the inhabitants of Earth. On the Moon itself, this lunar month of 29.53 Earth days would rather appear to denote a full set of phases of Earth, e.g. full earth to full earth, except that this definition of month would seem irrelevant to anyone living on the Farside from which Earth was never visible.

Rather, to the Lunar Settlers, this period, called a lunation by our astronomers, will simply signify the period from sunrise to sunrise or from sunset to sunset – wherever they happen to live on their adopted new home world. From a Lunan's point of view, it's all about where the Sun is in their sky, and has nothing to do with Earth at all. Earth could cease to exist and there would be no more "full moons" or "new moons" to reckon by. Just the interval between sunrises (or sunsets).

Introducing "the Sunth"

Accordingly, pioneers might well prefer to call it simply the "sunth." This term is less stuffy than "lunation" which is really a geocentric term signifying the period from "new moon to new moon." The term "sunth" avoids confusion with our own Earth calendar months of Roman origin which do not coincide at all with lunar months as they average about a day longer in order to divide the year into twelve neat periods with no leftover days. The Sunth then would be the natural way of reckoning the passage of time on the Moon.

The sunth will also be the primary consideration in scheduling activities which depend upon the availability of sunlight and/or solar power. This will include mining and industrial operations, road building and prospecting. The local time of sunth will also determine the timing of agricultural chores.

M IS FOR MERIDIAN:

The Replogle globes of Earth and Moon alike are divided into 15 degree longitudinal segments. For the Earth, this is a natural, since 15 degrees is the width of the idealized "time zone" ($15 \times 24 = 360$).

On the Moon, however, the slow daily crawl of the terminator line dividing sunshine from darkness is just over 12 degrees (12 deg., 11 min., 27 sec.). So for the purposes of settlers of the Moon or for people on Earth who want to better comprehend what life on the Moon would be like, future Moon globes might display meridians marked every 12 degrees. Thirty 12° sections equals a full circle of 360° . Thirty quasi "date zones" if you will. Even if these zones do not precisely measure the sun's slow crawl across the sky they would offer a close enough approximation to allow Lunan students and others to easily estimate by how many dates the sunth is retarded or advanced in his/her location in comparison to other settlement sites and outposts on the Moon.

M IS FOR METONIC PERIOD:

A 5th Century B.C. Athenian by the name of Meton noticed that the Moon's phases returned to the same dates of the year after 19 years (i.e. 228 calendar months = 235 lunar months). The Metonic period is important for anyone who would devise a calendar which respected the 29.53 day lunar month or sunth, and yet reconcile it with Earth's 365.25 day year at least periodically. **MMM**

Moon Calendar

A Moon Calendar for Lunar Settlements

By Peter Kokh kokhmmm@aol.com

To be sure, there will be settlers on the Moon with "Tory" hearts, i.e. unwilling to give up the ways of Old Earth, however inappropriate to the new world. Earth's calendar is one such piece of baggage best left at home. On Earth, counting time by "moons" may be convenient for nomads and rustic hunter-gatherers, but the overriding temporal fact of life since the dawn of the agricultural age remains the length of the year: the four seasons.

But on the Moon, however, the four seasons do not apply -- except for astronomers. The overarching pacer of life will be the sunth (see M is for Month, above).

Since the slow rhythm of sunrise and sunset cannot be ignored on the Moon, the calendar should be organized around it, no ifs, ands, or buts.

Keeping the standard 24 hour day/date

Because of Earth's proximity to the Moon and the high density and intensity of Earth-Moon communications and commerce (as compared, for example, to Earth-Mars intercourse), it will be convenient to keep the standard 24 hour day -- probably called "date" on the Moon to avoid confusion with the longer sunth.

A simple calendar of alternating 29 and 30 date sunths will do the trick, especially if every fortieth date (or on the closest weekend thereto) an extra hour is added (as we do in the fall switching from daylight-savings to standard time) to make the sunth average 29.5 dates exactly.

Then a two page calendar would always be valid even as to the times of local sunrise and sunset to within the hour, per location.

This system would be enhanced greatly if the sunth were four weeks exactly, which would require adding an eighth day three weeks out of eight.

Advantages of an occasional 8-day week

Such an extra day would be a logical choice for religious feasts and holy days and for secular holidays alike. Since the extra day would not be a working day but an off day providing three long weekends out of every eight, it should be a popular feature and add cultural color to life on the Moon.

This way sunrise and sunset would occur, for a particular place, not only on the same dates of the sunth but also on the same days of the week which will be important for business and industry (see article: POWERCO in this issue)

Naming the days of the Week

Since, obviously, lunar weeks and weekdays would not line up or keep cadence with those of Earth (no need to), new names are in order. Let me offer three possibilities, naming the days of the lunar week after:

▫ **The major moons or satellites of the solar system:**

Luna, Io, Europa, Ganymede, Callisto, Titan, Triton (plus 3 weeks out of 8, **Titania**)

▫ **The stars in the Big Dipper** or Plough visible on the Moon anywhere north of 30 degrees South:

Dubhe, Merak, Phad, Megrez, Alioth, Mizar, Alkaid (a plus 3 weeks out of 8, **Alcor**)

▫ The stars of the Pleiades which can be seen from almost anywhere on the Moon:

Alcyone, Merope, Electra, Celaeno, Taygeta, Asterope, Maia (plus 3 weeks out of 8, **Pleione** and/or **Atlas**) They were the parents of the famous seven sisters).

Note: "Pleiades" was the name chosen by Artemis Society International, for its original short-lived newsletter.

Fiscal Considerations

For fiscal and accounting convenience -- divisibility into "quarters," for example -- the calendar should have twelve sunths invariably -- like the Islamic model rather than the Jewish one (which sometimes has thirteen). This would yield a short "year" or "ennium" of 354 dates that would slip seven sunths out of alignment with Earth's calendar after nineteen years (see M is for Metonic Period above: 19 years & 235 Sunths)

So every nineteenth year an extra seven sunth period could be added, to be called "the Renaissance" and devoted to constitutional and institutional renewal, reform, and rededication, thus bringing the Moon's calendar back into step with Earth's and providing a predictably popular generation-long rhythm as a creative fringe benefit of which lunar civilization could be proud.

There are alternatives of course, but why compromise with those inappropriately attached to terrestrial customs. It's a brand new world and why not start fresh with new traditions? "Tories" can always import Earth calendars and keep them under their pillows. **MMM**

This article is online at: <http://www.asi.org/adb/06/09/03/02/008/mooncalendar.html>

ESSAYS IN 'M'

By Peter Kokh

M is for Mare Moscoviensis. The “Sea of Moscow” is the prominent mare area in the far northeast quadrant of the Lunar farside. In flagrant violation of the tradition that calls for Lunar Seas to be named after weather phenomena, states of mind, or directions, the Soviet discoverers of this farside lava plain exercised their naming prerogative and christened it after their largest city. I have come upon the apology that, after all, “Moscow is a state of mind.” Now I must confess, having been there, that there is some subtle truth to this claim. Moscovites are justly immensely proud of the assets of their 850 year old city, carefully nurtured and built-upon generation after generation. In the interests of good will, I’ll withdraw the complaint if the free translation of Mare Moscoviensis as: “Sea of Civic Legacy” is allowed. :-)

M is for Marequator (Mare + Equator) – an imaginary “great circle” belt around the Moon that crosses the Lunar equator near the limbs between nearside and farside, and rises to about 30–35° north near the longitude that passes through mid-nearside (0°) and descends to about 30–35° south near 180°, the longitude bisecting farside. (see the maps in the Farside I article this issue) Such a line seems to evenly bisect both the major mare features of nearside and the skimpy farside placement. Someday a circumlunar highway might logically follow such a route. Another possibility is a superconducting lunar girdle along this path, with regularly spaced solar power stations, half of which will always be in full sunlight, endowing this “dynequator” with continuous abundant energy to be conveniently tapped by most “coastal” (mare shore/highland coast) settlement sites. A magnetic levitation rail route for high speed inter-settlement travel would be a logical adjunct. MMM

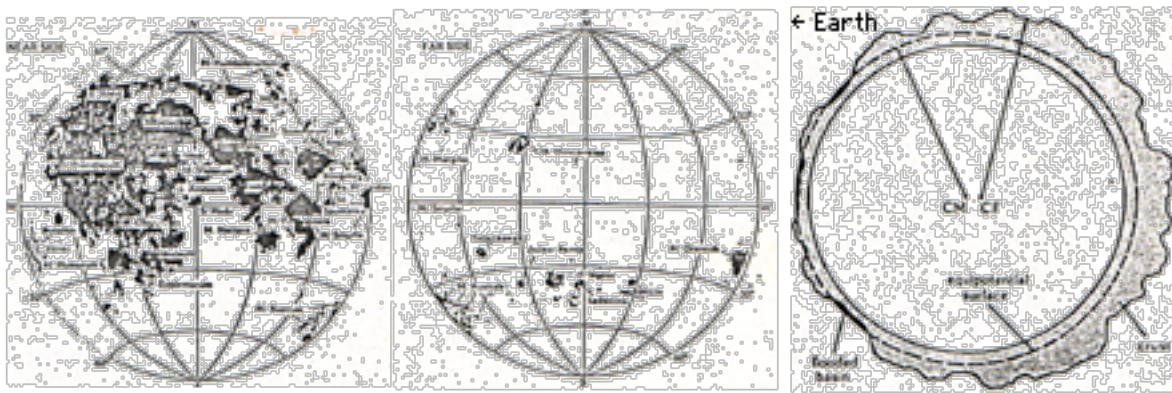


PART I: Lunar Asymmetry as a Clue to the “Origin Question”

FAR SIDE PART 1 By Peter Kokh

To many of you in your teens, twenties, even early thirties, the “Farside of the Moon” conjures up no special images. You’ve always known (or have been able to look up) what that face of our satellite forever averted from Earth looks like. However, for those of us who came of age well before 1959, the term “Farside” will forever carry a lingering thrill of mystery. For all of mankind’s history up to that point, now one had ever seen, even vicariously, the back 41% of the Moon that its elliptical orbit-locked rotation kept forever out of sight from Earth-bound vantage points.

Speculations, of course, abounded, with little to limit them. The most popular and grating misconception was that the “far” side was synonymous with “dark” side. However, these outfacing lunar precincts are equally blessed with the alternating relentless glory of solar was shaped like some pushed-in deflated beach ball, folded in on itself, so that with the foundations of the rear face up against the roots of the front face, the back was some enormous hollow holding atmosphere, water, life, and of course, a mutually unsuspected and unsuspecting civilization whose differences from our own were left to one’s fancy. In contrast, most scientists and educated laymen fully expected the mystery side to look much like the familiar side, i.e. a complex pattern of lighter crater-pocked highlands, and darker mare planes, seas of congealed lava-basalt.



[Illustrations from “Planetary Science: a Lunar Perspective” by Stuart Ross Taylor, pp. 266, 267, 346]

Suddenly, on October 4, 1959, two years to the day after the orbiting of Sputnik I – the Soviet probe Luna 3 in an equally epochal feat, returned the first crude low-resolution photographs of the previously unknown hemisphere which showed at once that while this newly revealed hinterland of Earth’s faithful; orbit-mate had the familiar elements of lighter highlands and darker plains, the proportions were startlingly different, and unsuspected. While the basaltic floods cover a major portion (37%) of the hemisphere that charms Earthbound lovers, creating the “man-in-the-moon” naked eye visage, these lava upwellings have pooled in only a few small and scattered basin bottoms on the aloof side, making it far less photogenic.

At first, no one could suggest a plausible reason for such a surprising variance. But further probes revealed some salient facts. First, the Moon was not all that round. Rather it was slightly egg-shaped with the pointy end facing Earth. Second, the Farside did have great basins just like those on the nearside: the South-Pole_Aitken basin is considerably larger than the familiar Mare Imbrium, the Sea of Rains. But these basin were largely “dry” – not flooded with post-impact upwellings of lava. So these basins are categorizes as thalassoids – “sea-like” rather than maria – seas. Only a few basins-within-basins are thinly and irregularly covered with mare-like floods. (I like to call a small, irregular, and isolating pooling of mare-like deposits a diluvium [plural diluvia] from the Latin word for flood.

Further orbital data eventually suggested a partial explanation. On the Earth-facing side, the lunar crust is perhaps 60 km (37 miles) thick, whereas it averages closer to 100 km (62 miles) thick on the private side. Thus the molten magmas of a younger lunar interior had further to go to reach surface release.

Why this crustal different? In the absence of hard data from Apollo or Luna sample-return missions to substantiate any answer, the prevailing wisdom is that the farside crust must be substantially less dense in composition and unlike the nearside highlands it superficially resembles, so as to float higher above the underlying mantle.

It is pardonable that public and private curiosity, driven as they are by the notoriously short attention span of the media, did not allow follow-up sampling missions to these regions to fill in the pieces of what remains the great puzzle over the origin of the Moon. Is the Moon a breakaway daughter of the Earth? Or is it a stunted sister, having evolved side by side from the onset of planet formation? (the pacific basin is much too young to represent a “scar” of such an event.) Or is it a successfully wooed spouse, born and bred elsewhere in the Solar System?

The substantial differences in chemical composition between the lunar and terrestrial crusts seems rule against the first two suggestions, while a successful capture scenario has never been developed to support the third contention. A recent hybrid offering attempts to solve both constraints. According to this hypothesis, the early still-forming Earth was hit at just the right angle by a “Mars-sized” planetesimal (how can anything “Mars-sized” be “-esimal”?) vaporizing a significant portion of proto-Earth’s pristine crust, the volatile elements escaping in the process to account for the chemical differences (the Moon’s crust being generally volatile-deficient) and the heavier refractory elements recondensing in Earth-orbit to form the Moon. This new thesis is gaining widespread currency and might be called the Eve theory (i.e wife from husband’s rib.) I propose we call the suspected “Mars-sized planetesimal” Velikovsky. Apparently we are now to believe such billiard-ball events respectable, so long as they are surmised to have occurred in conveniently early eons!

I remain unconvinced, for two reasons. First, in the absence of plans (except by the World Space Foundation) for probes to Sun-hugging Mercury that could answer the question, I feel that Mercury's crustal composition may be similarly volatile-depleted and bear a far closer match to Lunar element and isotope abundance patterns than the above hybrid thesis can explain. Second, the new impact residue theory leaves totally unaddressed the reasons for the great front-back hemispheric topographical and crustal symmetries in the Moon that were pointed out above.

Rather I would offer instead that this nearside-farside asymmetry is an accident of capture, an encounter with an aboriginal Earth satellite retinue that remain undigested because the Moon was already far along in its differentiation and consolidation at the time, being perhaps the one last major planetesimal forming in Mercury's orbital domain that instead of being assimilated to the quicksilver planet was ejected from its orbit by Mercury in a close flyby pass, the action-reaction relic: Mercury's present atypically high orbital eccentricity and inclination, not to be expected so close to the Sun.

In the absence of contraindicating Mercury sample-returns to disabuse me of this notion, I believe that the new desiccating-vaporization-splashout myth of lunar origin has severe weaknesses. To boot, few question Mars' capture of Phobos and Deimos. MMM

MOONSPORTS

MOON SPORTS By Peter Kokh

One can easily think of non-team sport activities that might work well on the Moon: gymnastics, swimming, road rallies, etc. But you can scratch sailboating, sky-diving and other such outdoor sports.

Physical Constraints on Moon Sports

But what interests me here are the possibilities for spectator team sports. On the Moon, "sixth-weight" (1/6th G) will allow balls to bounce higher and travel farther (though, middoors, air resistance will have its customary effect) and at the same time reduce players' traction, maneuvering, and braking abilities, all while momentum remains quite "Earthlike."

Promising and not-so-promising models

Even with a greatly deadened basketball, for example, the game as we know it could not be played. The bounce, even if restrained in height, would be slower, and players could not dart about the court as easily, dribbling in slow motion. Baseball, Football, Soccer, and Hockey would be similarly affected. Rather than produce caricatures of familiar and beloved sports, it would be better to start fresh, and invent substitute sports from scratch.

Better candidates for adaptation, serving as a point of departure for "designer Moon Sports" might be handball or racquetball, or its exciting distant Basque relative, Jai Alai (pronounced Hi-a-lye) [a game like handball, played on a walled court with a hard ball, popular in Spain, Latin America and parts of the United States (Florida); pelota. The ball is caught and thrown with a curved wicker basket fastened to the arm - World Book], but without the parimutuel trappings. For lunar adaptation, the side walls could be thick one-way glass, allowing spectators to sit behind.

Table tennis or ping pong, bowling, and such small-field sports as lawn bowling, croquet, and miniature golf might work well enough, but these are not substitute for the big spectator sports. What can we do now, here on Earth, to help give future lunar settlers a head start in this direction?

We would need to simulate lunar conditions. An awkward and certainly unworkable "game plan" would be to do so by tying carefully metered helium balloons to athletes' arms, legs, and torsos to simulate reduced weight and traction along with undiminished momentum. A much better idea is computer simulation, in which all the effects of sixthweight on traction, acceleration, speed, bounce, trajectory, braking, etc. could be taken into account. Gaming rules would certainly be affected. Side walls could be as important as the playing field or court customarily considered. All the elements of a proposed game must be varied: number of players, type of ball and/or other equipment, dimensions, rules etc. until a computer simulation resulted that promised exciting, ever interesting and gripping play.

On Earth, we have already taken preexisting games as points of departure and created new sports which bear only a curious relationship to their design ancestors, Thus, English Rugby is a distant precursor of American Football and English Cricket of American Baseball. On a hunch, I'd recommend any would-be Lunar contact sport designer would do well to consider Rugby for inspiration.

Income-generating sports telecasts

The goal is a number of sports well-enough designed not only physically but in game play to excite spectators and keep them coming back, resulting not only in whole new sections in the Guinness Book of Records, but in heightened Tourist Lure! The "Saturday Wide World of Sports" TV show would have to change to "Wide **Worlds** of Sports" as telecasts of Lunar sporting events to Earth become commonplace and finally bring home to "Joe 6-Pack" in his Earthbound armchair that, yes, the "world" has expanded to include new turf.

Such telecasts could be a source of considerable income to the settlements, adding in both royalties and purchases of commercial time for sponsors. And here and there will be the young Earthling who will crave to try these sixthweight sports, which he/she can now only passively watch, kindling in them the first ardors of a yearning to join the settlers someday. MMM

MMM #10 - November 1987

Pioneers' Lunar Astronomy Quiz

QUESTIONS

1. How many square degrees are there in the sky?
2. Our stellar coordinates are based on Earth's equator and axial tilt. This is too home-world-chauvinistic a system to take with us to the Moon and beyond. Using celestial coordinates based instead on the ecliptic, the plane of the Earth's orbit around the Sun, is also chauvinistic but would be acceptable to astronomers on the Moon since the Moon shares that plane. But anticipating mankind's spread beyond Earth-Moon space into the Solar System at large, what coordinate system do you think a "Union of Solar System Universities" might adopt?
3. Has any astronomy been done from the Moon?
4. Who was the "Father of Radio Astronomy?"
5. What is the north "Pole Star" of the Moon?

ANSWERS

1. **4 π steradians** or square radians. A radian is $67^\circ 17' 44.80624''$ so this works out to $41,253^{\circ 2}$ (square degrees.) This encompasses all vectors. If you are situated on a planetary surface, half of this (20,626.5 square degrees) is underfoot and half "in the sky" i.e. above the horizon.
2. **The orbital plane of Jupiter**, inclined to "our own" "ecliptic" by $1^\circ 3'$. Not only is Jupiter the largest and most massive planet, but close to 75% of the angular momentum of the entire Solar System, Sun included, lies in Jupiter's motion in that plane. That would make Jupiter's ecliptic the logical standard for the whole Solar System. Transposition of coordinates, thanks to computers, will not be a big deal. We already transpose our own to keep up with the precession of the equinoxes as the points in the sky at which Earth's poles aim rotates in a circle around the poles of the ecliptic over many millennia.
3. **Charles M. Duke II**, an astronaut on the Apollo 16 mission to the Descartes region, became the "father of lunar astronomy": when he took astrophotographs of interstellar gas clouds and of the ultra-violet halos around some galaxies (April 21, 1972.)
4. In the early 1930s, **Karl Jansky**, a young radio engineer at the Bell Telephone Laboratories, concerned about the ever-present static that is part of radio reception, detected a very faint but steady noise that could not be traced to any mundane source, and concludes that it came from space. By 1933 he had pinpointed the direction of the source. It lay in Sagittarius towards the center of the galaxy. He received little recognition before his death.
5. **Zeta (z) Draconis**, a 3.2 magnitude star some 600 LY away. [see chart] This is also the north polar star of the Sun and of the entire Solar System [read: Jovian ecliptic] and as such is the center of the

circle traced in the heavens by Earth's north pole as it precesses through a circuit every 25,750 years (Polaris just happens to be our Pole Star during the present period.) Thus z Draconis is "the pole of our pole" so to speak. Perhaps in time Zeta will be appropriately renamed "Zenith Draconis". And at the opposite pole is the Large Magellenic Cloud (Nebecula Major) at "Nadir Doradus."

ESSAYS IN "M" Focus on Farside

By Peter Kokh

M is for Means of Transportation to and from a Farside Astronomy site.

Powered portions of rocket (suborbital or not) landings and ascents to and from the lunar surface, ought not to be allowed in line-of-sight from a Farside Radio Astronomy installation in order to avoid interference. Instead "Farport" ought to be located at the end of a surface road from the radio telescope facility at least ten or more degrees away and around the Moon's curvature [c. 200+ mi or 300+ km]. It might be best to locate Farport inside the farside zone which is within line-of-sight of the L4 and L5 Lagrange points at all times, say within 35° of the central Farside meridian. Then communications too would be routed via-surface cable to Farport before being relayed to/from the S.E.T.I. telescope facility.

M is for Monastery.

Despite serious inroads both by the age of skepticism and by the current preoccupation with self-fulfillment and self-gratification, a small hard core population remains drawn to contemplation-with-service, free from the burden of life's many distracting hassles. Such persons offer a psychologically stable manpower source that could be tapped for support of personnel at outlying lunar bases and installations (such as an isolated Farside Radio Telescope Installation pursuing the Search for Extra-Terrestrial Intelligence) where a full-spectrum-city-life is unlikely to develop. While they might not reproduce their numbers, neither would they come for limited tours of duty. They would certainly find the "atmosphere" congenial to their way of life.

Here in deep Farside, with Earth never above the horizon, with telecasts from Earth blocked by the Moon's own mass, and with the Milky Way unimaginably brilliant in the nighttime skies, will be an ideal site for a monastery tasked with the S.E.T.I. search. ###



FARSIDE Part II. The Ideal Site for Frontline Astronomy

By Peter Kokh - <http://www.asi.org/adb/06/09/03/02/010/farside.html>

A popular theme of science fiction has long been the idea of using the Moon, and particularly the lunar "farside", as a platform for astronomical research. The advantages the Moon offers over today's orbital satellite astronomy are considerable:

1. **Shielding over 50% of all vectors** (2 p steradians), and with it, halved exposure and vulnerability to cosmic rays, flares, and micrometeorites
2. **Greatly reduced radiation** coming from particles trapped in Earth's magnetosphere and Van Allen Belts
3. **Vastly reduced vulnerability** to the swiftly multiplying trash-belt of cavalierly discarded space junk, a trend which, if not soon reversed, will eventually render LEO orbits unusable
4. **A rotation rate 400-500 times slower** (0.5 degrees or 33 arc minutes per hour versus 240 degrees for the typical LEO-sited facility, and with it the possibility of long exposure times of up to two weeks or more, extreme stability, and long integration times
5. **Ease of access** for maintenance and changeout of equipment

6. Low 1/6th g which will be a mechanical plus in comparison to both 0g and 1g and which will allow very large instruments and which also serves to scavenge dust out of the environment very rapidly (not so in the "Sargasso sea" environments of LEO, L4, and L5.)

These advantages over LEO facilities are available anywhere on the Moon. Even for radio astronomy, the Earth presents a far smaller cross-section and can conceivably be baffled out-of-sight, especially since Earth's position in any nearside sky remains fixed within libration limits of a few degrees.

Radio astronomy has been at the forefront of astronomical research for more than two decades. At first very crude in its resolving power, integrating arrays of radio telescopes can now achieve angular resolution and detail that optical astronomers can only drool over. But the problem arises with interference from man-made radio and TV signals which make for poor listening even as Earth's thermally shaky atmosphere makes for poor seeing for optical instruments. The idea, long a favorite in science fiction, has been to put radio telescopes beyond reach of such interference on the far side of the Moon. Here we can best listen to the "music of the spheres" from natural astrophysical processes and, some hope, from intelligent species, if there are any out there trying to make their presence known.

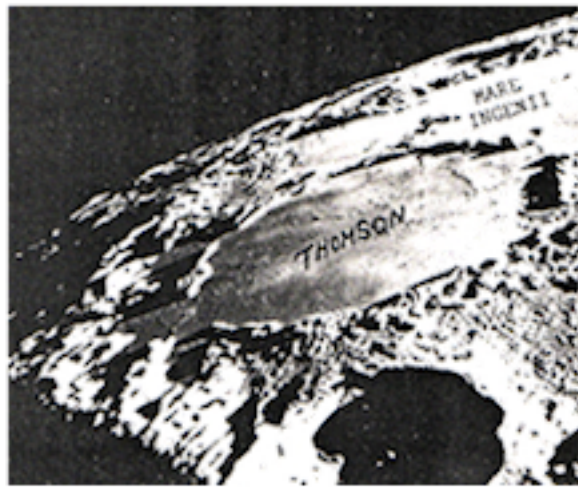
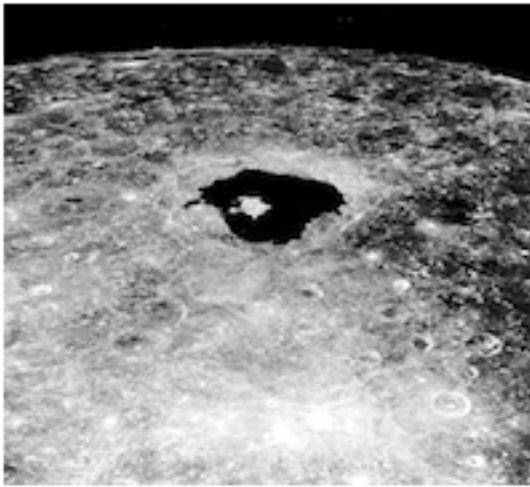
FARAF – Farside Advanced Radio Astronomy Facility

Not just anywhere on Farside will do, however. Not only should such an installation be closer to the equator than the lunar poles, so as to cover as much as possible of both celestial hemispheres, but it should be in the shadow, not just of Earth-direct transmissions but of indirect relayed transmissions from the L4 and L5 Lagrange areas, 60° ahead and behind the Moon respectively in its orbit about the Earth, where the Moon's version of synchronous communications satellites will be placed.

Line-of-sight exposure to L4 and L5 encroaches 60° or more (if "halo" orbits are used) on each flank of Farside thus ruling out such otherwise ideal sites as Tsiolkovsky crater, Mare Orientalis, and Mare Moscoviensis. Rather, only a central "orange-slice" between 155° E and 155° W ought to be considered, restricting outposts to 25° either side of the central Farside meridian, 180°. And a treaty or convention may be needed to prohibit the use of the L2 Lagrangian position behind the Moon for anything but intermittent tight-beam transmissions on a non-casual emergency basis only. Laser-based communications relays via L2 to Farside points are a possible substitute. If such alternative communications systems cannot be developed, it may be necessary to make Deep Farside off-limits to home-steaders except at, around, and in support of FARAF.

We have already mentioned some mare/diluvium-floored Farside locations that must be ruled out. Highland type sites abound, of course, and the ivory-tower ideal site at 0° latitude (the equator) and 180° E-W is on highland terrain. However, this would limit us to highland-sourced building materials and rougher topography than would be available at a highland/mare "coastal" or "near-shore" site which would offer the advantages of both kinds of soil and terrain. Further, mare-like areas will be vastly superior for such extended installations as a Socorro (NM) type Very Large Array or even for its design-archetype, the "Cyclops" Array.

Unfortunately, there is no such mare/ coastal site anywhere near dead-center Farside. The site I suggest is northeastern Mare Ingenii (variously translated as the Sea of Engineers or the Sea of Ingenuity) centered about 168° E and 32° S. While this location is further south than one might wish, it will still allow full coverage of the entire Milky Way and such important nearby galaxies as M31 (Andromeda) and M33 (Triangulum). Bear in mind that, on the Moon, the apparent celestial equator will more nearly coincide with the ecliptic -- the plane of the sun and path of the major planets.



Left: dark basalt floored Tsiolkovsky stands out. **Right:** flat-floored Thomson Crater

The view of Thomson / Mare Ingenii is towards the south, opposite the orientation of lunar maps.

Mare Ingenii is located at the “antipodes” of the impact center of the Mare Imbrium basin which is the largest basin on the Moon’s Nearside. The area has a vestigial local mini-magnetosphere, probably an artifact of the plasma that flowed around the Moon in all directions to this location from the Mare Imbrium impact. This mini-magnetosphere might offer some feeble protection for astronomical instruments from the solar wind.

Mare Ingenii is incompletely and thinly covered over much of its expanse with mare lava sheets. The best flooding conveniently occurs in the large (70 mi = 112 km) Thomson Crater in the ENE part of the Mare Ingenii basin. This is surely the ideal site for the next generation VLA (Very Large Array), a “Y”-shaped array of movable, tracked, steerable radio telescope dishes that can provide significant resolving power, working in concert. Ancillary smaller outlying installations for further image integration over longer baselines could be placed at convenient Farside sites outside our “orange-slice” preserve. (It goes without saying that a competing free space array anchored in L4 and L5 with a baseline of about 400,000 miles (643,000 km), should also be built and teleoperated from central Nearside.)

On Thomson’s north crater rim are some small deep craters that might prove suitable for a large unsteerable Arecibo-like dish, appropriately scaled up as far as the reduced lunar gravity will allow. Nor need our Mare Ingenii-Thomson site be restricted to radio astronomy. Dedicated optical/infrared observatories concentrating full-time exclusively on the two Magellanic Clouds, the major companion satellite galaxies of our Milky Way, lying at (LMC) and near (SMC) the lunar celestial south pole and always above the horizon from our proposed FARAF site, are a logical adjunct.

What about the supporting settlement itself? Not only will astronomers and technicians be needed, but also support personnel to grow food and maintain the life-support systems, in short a whole community of eventually some hundreds. And what about a name for the place? Thomson City? Or tired, stuffy names related to the history of radio astronomy or SETI such as **Marconi**, **Sagan**, **Jansky**, **Spielberg**, or New Socorro? Personally, I would like to see something more suggestive of the special vocation of this unique settlement such as **Sussuri** (Latin for ‘whispers’, i.e. of the stars) or simply **Stellarum** (Latin: ‘of the stars’).

Sussuri would have a very distinctive ambience. Earth would be out of sight and out of mind. The sunless fortnights would be dominated by the Milky Way in spectacular unrivaled brilliance. The whole mentality would be outward-oriented, astro-empathic, in tune with the stars (and any supposed intelligent species circling them). A major hobby will be brainstorming end-runs around the restrictions imposed by the speed of light and the shortness of human lifetimes.

The psychological distance of Sussuri from Earth and its flesh-pot distractions will be far greater than any physical quarter million miles. For some, not all, of course, Sussuri could be a stimulating place to live out one’s twilight years.

MMM

RURAL LUNA

LIVING IN THE "BOONDOCKS" CAN BE RELATIVE!

RURAL LUNA By Peter Kokh

If the Moon, all 14.5 million square miles of it, is not "rural," what is? To be sure, the first beachhead bases will be preoccupied with doing Lunar Science and successful demonstration and pilot plants for the production of Liquid Oxygen from the fine lunar soil. Such footholds will hardly amount to small "hamlets".

But upon first expansion, the Moon bases will concentrate on feasibility demonstrations of various forms of lunar-sourced construction; they will then proceed to the manufacture of a spectrum of building products for use locally, in Earth orbit, and in Mars orbit. Leveraging on these beginnings, if we make a serious effort to fully diversify on-Luna manufacturing to exploit the LEO and Mars markets, then one or more genuinely urban biospheres will arise.

So back to the question: given this incipient "urbanization" of one or more lunar sites, will there be any room on the Moon for homesteaders who prefer more elbow room and looser ties to civilization?

Well beyond the outskirts of "The City" (until there is more than one, locals may not pay much attention to proposed proper names), there may be a growing number of mobile nomadic science / prospecting camps searching for economically abundant concentrations and deposits of useful elements that exist only in taunting traces in the soils around The City. If such lodes are found, new settlements may be founded to mine and ship them to urban factories or to render them into marketable products on the spot. Depending on the market for such products, the new site may remain a rural village or grow to become a rival city. Bear in mind that rich concentrations of specific ores are not to be expected on the Moon except in a few Sudbury-like astroblemes, relics of the impact of particularly mineral-rich asteroids. On Earth, most ore deposits have been laid down in multi-million year long episodes of hydrotectonic leaching, a process probably unique to Earth and lo in our Solar System. But there are different soil types: highland soils, and a variety of mare soils deposited by successive episodes of lava flooding. Further, some crater central mountain peaks may be upthrust mantle material such as relatively denser pyroxene. The prizes will be useful concentrations of copper, platinum, lead, etc., all of which are unlikely.

Both underneath sites well known for the reddish glows of TLP ("transient Lunar phenomena") and elsewhere (where there are no 'leaks') there may lie deep underground pockets of unreleased volcanic gases or volatiles. No matter what their composition, detection of these reservoirs will likely lead to new homestead locations. Particularly harvestable water ice and / or carbon dioxide ice deposits (when mixed they are called 'clathrate') will call for at least temporary encampments as well.

Thus a number of lesser towns or even rival cities may develop, all feeding the local lunar economy, which in turn supports ventures in LEO (Low Earth Orbit) and in the Mars PhD area, and sooner or later in the L4 / L5 locations. Roads will be built apace, and along them, at intervals, will be needed way stations that support road maintenance, refueling, vehicle repair, closed life support system re-charging, flare shelter, inn-space, food, first aid, communications, etc., and probably serving not only travelers and truckers along the main routes, but off-road excursions for tourists, prospectors, and scientists.

Where the beaten path takes a long detour about some obstacle such as mid-mare wrinkle ridges, rilles (ravines that have resulted from collapsed lava tubes), or sand scarps, for example, is it not plausible that entrepreneurs might build bridges, fjords, or cuts and rightfully establish tolls for the shortcut they provide? Here and there, the run-of-the-mill lunar scenery ("once you've seen one crater, you've seen them all" is far from the truth) is relieved by some exceptional vista e.g. the Alpine Valley, the crater rims of such unique beauties as Aristarchus, Copernicus, Theophilus, and Tycho come to mind; such spots may support tourist inns.

A site along the east or west limb (90° east or west) will afford monthly Earthrise and Earth-set (caused by libration resulting from the Moon's eccentric orbit about Earth). The Earth will rise a few de-

grees clear of the horizon and a fortnight later be a few degrees below it, affording "twin skies": half the time a picture-window postcard scene of the Earth-kissed horizon, half the time (with Earth out of sight) the Milky Way will fill the sky with a brilliance we can only imagine. Here, especially along preexisting roads, would be a good spot for a honeymoon motel or a get-away-from-it-all retreat house, etc.

But not to wax too romantic, there will be dampening facts of lunar life. Firstly, to insure that there is a sufficient economic basis for such rural locations, a lunar authority would do well to license them, restricting them to minimum intervals depending upon current traffic volume projections. Survival without traffic support will be far, far more difficult than it is on live-off-the-land-friendly Cradle Earth! Applicants or applicant groups for rural openings may well have to bid for them, based on skills, abilities, talents, financial resources, and experience. At first the niches for such rustic rooting will be few, but they should grow exponentially as the multi-site economy expands and diversifies.

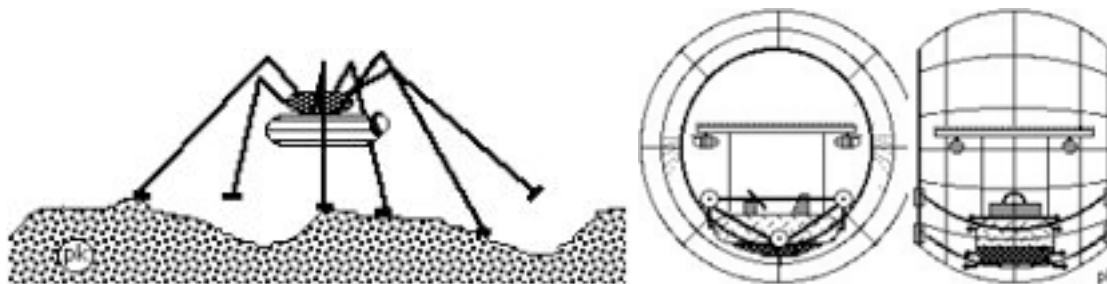
Secondly, hermitages and single family mines, farms, or inns, etc. may be both unsafe, and unendurable. The reason is that unlike on Earth, where we all share the same biosphere, on the Moon, each city, town, village, hamlet, camp, and isolated homestead must be a biosphere unto itself. And the smaller the biosphere, the less stable, less diversified, and less satisfying the sustenance it affords. Unless you and yours are stoics content to live on chlorella and algae mush, there will be a certain minimal size to any such isolated biospheres. To support a bare minimum exchange of service functions and division of labor as well as menu variety and social outlets, the village-sized, or at least hamlet-sized, island of humanity will likely be the smallest the Moon could support. As in lunar towns and cities, individual residences, greenhouses, workplaces, etc. will all be interconnected by pressurized passageways to afford the convenience and safety of integrated biospheres.

And you thought the Moon would be the ultimate get-away-from-it-all! Best head for some of the less settled areas of good old Cradle Earth! Our challenging gray neighbor may have room enough for small towns and villages, but the antisocial need not apply.

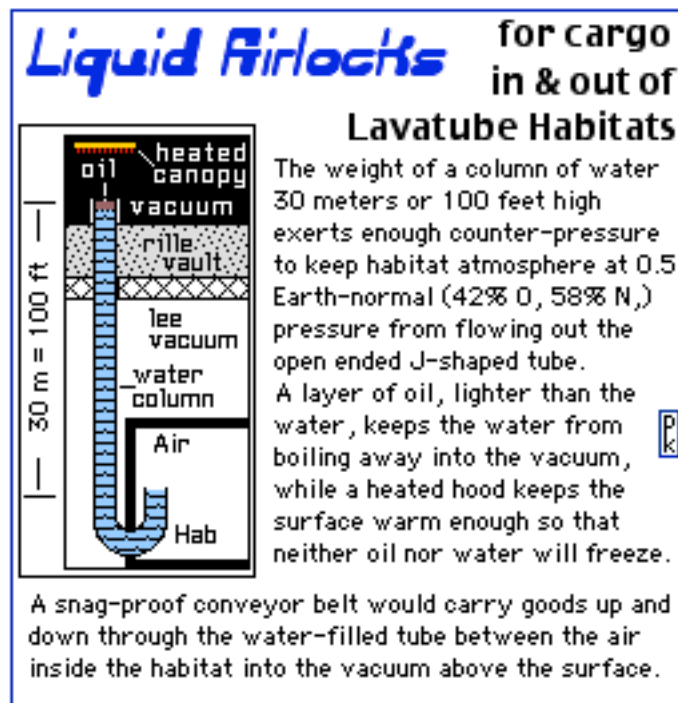
Such rural settlement as does occur will undoubtedly provide opportunity for diversification of food crops, meat animals, ornamental plants, and specialized arts and crafts. Separation combined with ingenuity and diverse mineral endowments will suggest unique feature products for which the town or hamlet may someday be renowned. Certainly, a rural subculture will arise. Radio, folk song and dance, and country ballads, as well as its own special etiquette, brand of hospitality, and 'ways' will instantly distinguish lunar rustics from city people. But they will share the Moon, a common bond which will set them uniformly apart from Earthsiders. The future of both urban and rural Luna will rise or fall together.

For the city dwellers, the existence of a number of rural communities will be both a safety valve and a constant source of cultural cross-fertilization and enrichment, as all Lunar citizens seek to continue their acculturation and adjustment to their new host world. The adventure should not be boring.

Peter Kokh April 1988



What better way to traverse "rural luna" with minimum disturbance of the terrain from a high perch where you can best see the moonscapes at their close-up best from a Spider, or all by oneself in this go-anywhere motor "squirrel cage."



INDUSTRIAL USE VACUUM-PRESSURE TRANSIT OF PRODUCTION ITEMS IN FULL OR PARTIAL GRAVITY, (REAL OR ARTIFICIAL) WITHOUT VENTING OF AIR

LIQUID AIRLOCKS By Peter Kokh

While many take a cavalier and could not-care-less attitude toward the preservation of lunar vacuum -- a precious industrial and scientific asset -- and seem thoughtless of the expensive non-conserving lifestyle which continuously vents costly import nitrogen through routine, frequent airlock cycling, this author finds both attitudes unacceptable and presents an alternative airlock-system to handle some important categories of traffic between pressurized and non-pressurized areas.

On the Moon or other airless bodies or in free space, where vacuum is already provided, a "barometric column" of a suitable liquid and of appropriate height, will seal in the atmospheric pressure of a habitat, factory, or warehouse via a U or J shaped tube.

AIR BAROMETER: a device for measuring atmospheric pressure. The average atmospheric pressure at sea level is 1 atmosphere which is the pressure that will support a column of mercury (Hg) 760 mm (76 cm or 29.92 in) high. This corresponds to the pressure exerted by a column of air about 5 miles (8km) high if its density were constant and equal to that at sea level. If a long glass tube which is sealed at one end and open at the other is filled with mercury and then is stood upright with the open end downwards in a dish containing mercury (or in a U-shaped tub open at one end) then so much mercury will flow out of the tub (or up the other, open end) until a column of mercury 760 mm in height above the level in the dish (or in the upturned open end of the tube) remains. The space above the mercury in the closed end of the tube is vacuum and contains no air. From: THE WAYS THINGS WORK, AN ILLUSTRATED ENCYCLOPEDIA OF TECHNOLOGY, Simon and Schuster, 1963. Page 220.

A continuous loop conveyor provided with the appropriate grip/release system with one end in the external vacuum, the other in the internal pressurized environment, will allow transit on a production basis without the venting of air (nitrogen and/or oxygen) such as occurs in the conventional vestibule-type cycling airlock, an early classic of science-fiction and still taken quite for granted by most writers, both technical and non-technical alike. (For Shame!)

Entry and Exit of "Routine Items" into/out of pressurized environments

Such a liquid barometric seal could become standard on the Moon (and, for example, on spoke-and-wheel shaped free space settlements) to allow entry and exit of routine items. For entry into pressurized environments, we think not so much of imports (from Earth or other settlements) -- these can be taken care of by "match port" docking -- as of those items which it is useful or efficient to manufacture in a vacuum but which will be used in the interior of the settlement. Metal and glass items are possible instances.

For exit, we think not so much of exports of items manufactured in pressurized environments and intended for use within other settlements -- or vehicles -- as of items so manufacture intended for use in vacuum. Of both categories (candidates for entry or exit) there should be several if not many instances. Very real losses of nitrogen, especially, but also of oxygen, can be avoided and vacuum degradation prevented, by the employment of such a liquid airlock system in well chosen cases. Two problems must be discussed.

- [1] The first problem is the availability of a suitable "barometric" liquid. Such a liquid should be fluid over a wide range of temperatures so that its utility is not constrained. A relatively high specific gravity or density would be a plus because it would proportionately shorten the required sealing column. It should have a low vapor pressure so that the rate at which it evaporates into the vacuum is slow enough to represent a substantial savings over the continual nitrogen loss that would result from the alternative reliance on a conventional cycling airlock system. Its cost of acquisition, by upport from Earth or by lunar sourcing should again be lower than the cost of the nitrogen conserved over the lifetime of its use.
- [2] Finally, such a liquid should be relatively inert, not corroding or otherwise adversely affecting either the items carried through it or the conveyor that carries them. It should drip off the exiting parts easily, both in vacuum and in air.

Candidate Liquids

Three possibilities suggest themselves. The first is Mercury (Hg), the densest choice by far. However, it is highly unlikely that mercury can be lunar-sourced. The cost of its upport must be added to that of its acquisition (purchase), and very large volumes of it will be needed, the cross-section of these industrial-scaled liquid airlocks being orders of magnitude larger than that of barometers and thermometers. Finally, mercury has a highly toxic reputation -- well-earned -- that would require very special handling on both ends. Despite its high specific gravity, we can pass over this choice.

The second choice is Gallium (Ga) which before its expected discovery was referred to as eka-aluminum. This element is very scarce but widely distributed on Earth in zinc blends and bauxite. Traces of it have been found in lunar soils, but it may be some time before it can be extracted economically in the quantities required for this prospective use which would be in competition with its desired service in gallium arsenide photocells for solar arrays (more efficient than the far cheaper silicon). Which usage would be more strategically important, I am not prepared to guess.

The credits of gallium are considerable. It is liquid from 30.1 °C - 1983 °C (86 °F .. 3601 °F) -- a very serviceable range for lunar and free space environments and industrial conditions -- and has a very low vapor pressure. Its specific gravity as a liquid is 6.081 (times as dense as water), which is very attractive, if somewhat less than half that of mercury. Of its inertness and benignness, I would not know.

The third choice is NaK (pronounced "knack"), a eutectic liquid alloy so-called from its constituents: sodium (Na) 23% and potassium (K) 77%. NaK, unlike its constituents, is liquid from a temperature not much higher than room temperature to about 800 °C -- again a highly serviceable range. Its thermal capacity is high. This, together with its expected economical lunar-sourcability will make it the industrial coolant of choice (instead of water/steam) for many lunar applications, possibly nuclear reactors among them. Against its cheapness as compared to other choices, Hg and Ga, must be balanced its low density or specific gravity which is comparable to that of water. This means that for its use in a barometric sealing liquid airlock system, the necessary column must be six times that of a system using gallium, and nearly fourteen times that of a system using mercury.

Nonetheless, while far from ideal, such high columns are still within the realm of practicability. Given the importance of the strategic goals (conserving nitrogen and preserving vacuum), all else considered, NaK is the logical choice. Possible showstoppers are its degree of inertness or lack thereof, of which I am ignorant, and the evaporation rate in vacuum, of which again I know nothing. As to its density, suffer a layman's naiveté to suggest experimenting with solutions of NaK and sodium disulfide or potassium disulfide, which might raise the value to a more practical level.

HEIGHTS OF BAROMETRIC SEALING COLUMNS IN VARIOUS GRAVITY AND PRESSURE SITUATIONS.

(The height is shown in meters with foot' and inch" equivalent given in parentheses)

Gravity: Earth-like situation (1.0 g)	Gravity: Mars-like situation (0.38 g)
Pressure: 1.0 ATM 0.5 ATM	Pressure: 1.0 ATM 0.5 ATM
Liquid	Liquid

Hg	0.76 (29' 9")	0.38 (15' 0")	Hg	2.00 (78' 7")	1.00 (39' 4")
Ga	1.74 (58' 5")	0.87 (34' 2")	Ga	4.58 (15' 0")	2.29 (7' 5")
NaK	10.33 (33' 9")	5.17 (17' 5")	NaK	27.18 (89' 0")	13.59 (44' 5")

Gravity: Moon-like situation (0.16 g)

Pressure: 1.0 ATM 0.5 ATM

Liquid

Hg 4.56 (15' 0") 2.78 (7' 5")

Ga 10.44 (34' 2") 5.22 (17' 1")

NaK 62.00 (203' 0") 31.00 (101' 7")

Note the extra incentive (besides the 63% savings in nitrogen supports) that the lower column height in 0.5 ATM provides (0.5 ATM consisting of 21 parts oxygen and 29 parts nitrogen or 50/100 ATM vs. 1.0 ATM consisting of 21 parts oxygen and 79 parts nitrogen or 100 / 100 ATM). NASA suggests this mixture as quite livable.

Application on Rotating Structures with Artificial Gravity

In rotating space structures with artificial gravity, the motivation to preserve the external vacuum disappears, but the economic necessity of conserving nitrogen remains, and the barometric seal liquid airlock will be a wise choice for the appropriate categories of goods traffic. The figures given above are valid to this venue as well. Thus a torus with 1/6th gravity (Moonlike) and 0.5 ATM internal pressure could be outfitted at each spoke with a liquid airlock with one end inside the torus and the other end piercing the ceiling on the side of the spoke and with a 101.7 foot column differential using NaK. This might come in especially handy for parts manufactured inside the rotating settlement for use in adding on to it from the outside. For a full 1.0G 1.0 ATM Stanford Torus, the corresponding column height would be 33.9 feet. The height in both cases seems eminently practical.

For Bernal Spheres and O'Neill Cylinders, liquid airlocks can still be used, but they must creep up the outside of the end caps and will be a mite trickier to use. To my knowledge, no one has discussed the possibility of liquid airlocks for either space settlements or lunar installations.

Application on Other Airless Worlds

The applications on other large airless satellites (Io, Ganymede, Callisto, and Europa in descending order of gravity) will be quite similar to those on Luna. But smaller bodies, e.g. Ceres, Iapetus, etc. will require column heights that would seem quite impractical -- many hundreds of feet or more. Economics will determine the cut-off point.

Engineering Challenges

The second problem -- for those of you waiting for the other shoe to drop -- is that of inventing (and patenting) the appropriate conveyor system with a grip / release system that probably must be design-specific for each type of production-line ware making the transit inwards or outwards. As we are dealing with a system open to vacuum on one end, the whole must be as thoroughly service-free as possible and operate without snags or jams. Here is where this neat idea must descend from the head-in-the-clouds abstract to the nuts-and-bolts concrete. The liquid airlock idea may be patentable in itself, but I doubt it, and the need for the real world experimentation is paramount; hence the lack of hesitation in throwing it out into the public domain.

Getting your feet wet -- Experiment!

For those of you itching to experiment with different liquids and diverse conveyor systems, but requiring the possibility of profits from here-and-now terrestrial applications markets, here are some possibilities to spur on this pre-spin: transit between everyday Earth environments and special atmosphere chambers using pure nitrogen, pure chlorine, pure hydrogen, or other gases; transit into and out of "clean rooms".

Such applications may seem sparse, but I venture they will be deemed important enough -- at least in some high-traffic instances -- to support the costs of research and development necessary. If this is indeed the case, here are avenues of experimentation which will put invaluable experience and knowhow "on the shelf" from where we can take them, at greatly minimized cost and delay, when we need them for space or lunar use eventually. Another important ULTERIOR VENTURE entered into for profit below and ulterior utility above. If we leave it to NASA, It wouldn't get done! It's not a need for a non-industrial outpost such as NASA has limited its vision to include.

MMM

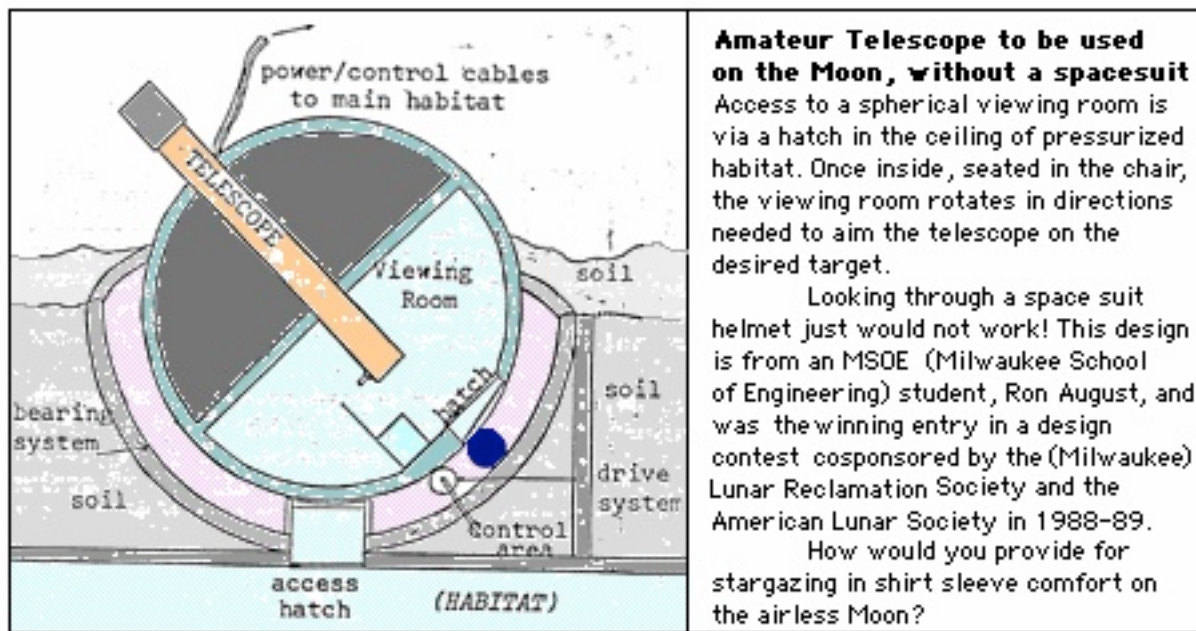
MAIL to MMM: The Moon's Atmosphere

I have been following MMM's debate on the use of nuclear power on the Moon. There seems to be the assumption that because there is no sensible lunar atmosphere, there never will be. Once we come to stay, however, that could change. The natural lunar atmosphere weighs about 10 tons, with a replacement and loss rate of about 50 grams per second. Most of it consists of solar wind particles enjoying a brief rest before rushing off again, and radioactive decay products such as radon waiting to be photo-ionized off into space.

Humans will probably be far messier than that. Gasses from pressure hull leakage, regolith processing, rocket exhaust, etc. will outstrip natural sources by several orders of magnitude. Unless we're exceedingly careful, the natural atmosphere would soon be merely a trace element in a man-made one that will be thick enough to stop the solar wind and some UV from reaching the surface. Under those conditions the lower portions of this nouvelle atmosphere will be protected from the main loss mechanisms and the stay time of typical air molecules may rise from weeks to millennia.

The future history of the Moon's atmosphere is hard to predict, depending as it does, on human activity and on the unknown absorptivity of the lunar surface. I don't suppose the air will ever get thick enough to tempt one to go outside sans spacesuit, but there will be enough, someday, to require appreciable changes in lunar hardware and operations. A thousand years from now, Earthlings may look up to see not only the lights of lunar cities, but also the ruddy, oxidized disc of a deeply tanned man-in-the-moon. Joe Suszynski

MMM #20 – November 1988



AN AMATEUR LUNAR TELESCOPE DESIGN

Note: electronic ways to channel a telescope image from a scope on the surface to a comfortable viewing area within a pressurized habitat were not admissible in this "engineering" exercise.

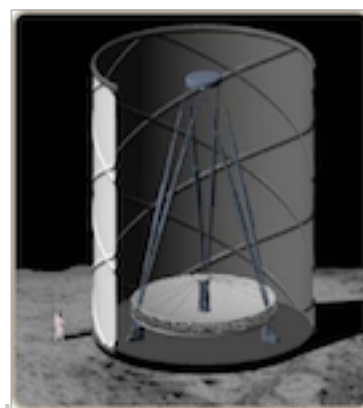
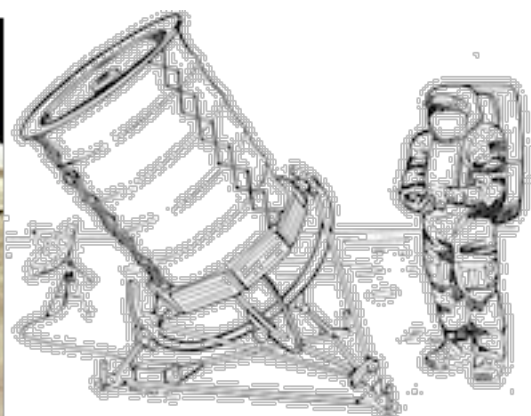
Submitted by Milwaukee School of Engineering (MSOE) student and MLRS member Ron August of Hubertus, Wisconsin. This concept involves a moving, spherical shaped viewing room, with the telescope an integral part of it, that is completely pressurized, heated, and accessible from the habitat below. Entrance to the room is by way of an airtight hatch system.

Once inside the viewing room, the observer will be strapped into a viewing chair which has all controls for movement of the telescope (and viewing room) and focusing of the telescope.

Movement of the telescope/room is achieved by a controller wheel which moves the room into position to point the tele-scope at anything above the horizon in all directions. The room is suspended by a low friction smooth-running bearing system.

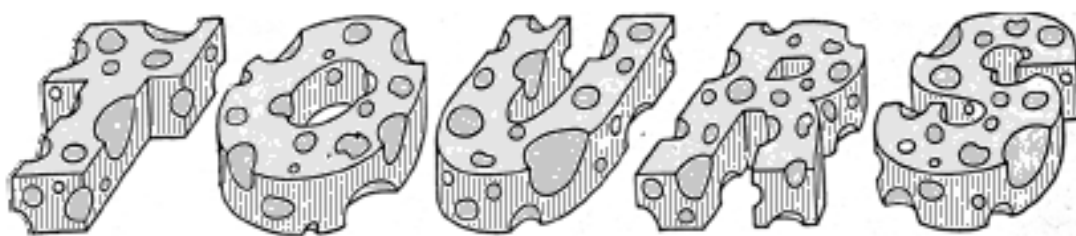
This was the winning design in a competition cosponsored by MLRS and the American Lunar Society. Two other entries received honorable mention, including one in which a zenith-pointing telescope had its base within the habitat, the shaft piercing the regolith shielding overburden and open to the vacuum. The scope turned in a sleeve using a barometric liquid seal and surface mirrors to redirect the view. (see MMM #17 "Liquid Airlocks" above)

NOTE: The editor has been well-received by astronomy club audiences over the years for his talk on how future settlers will pursue their amateur astronomy hobby. He has also stressed that through human presence, we will over time learn much more about the planets and moons. **MMM**



MMM #21 - December 1988

Earlier than
you think
**Lunar
Overflight**



LUNAR OVERFLIGHT TOURS 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

Space Fiction By Simon Cook

The sleek "silver sliver" of our Boeing 808B 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, Ecuador and began its streak for orbit. (At 9500 ft. elevation and smack on the Equator, Quito had become 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 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.

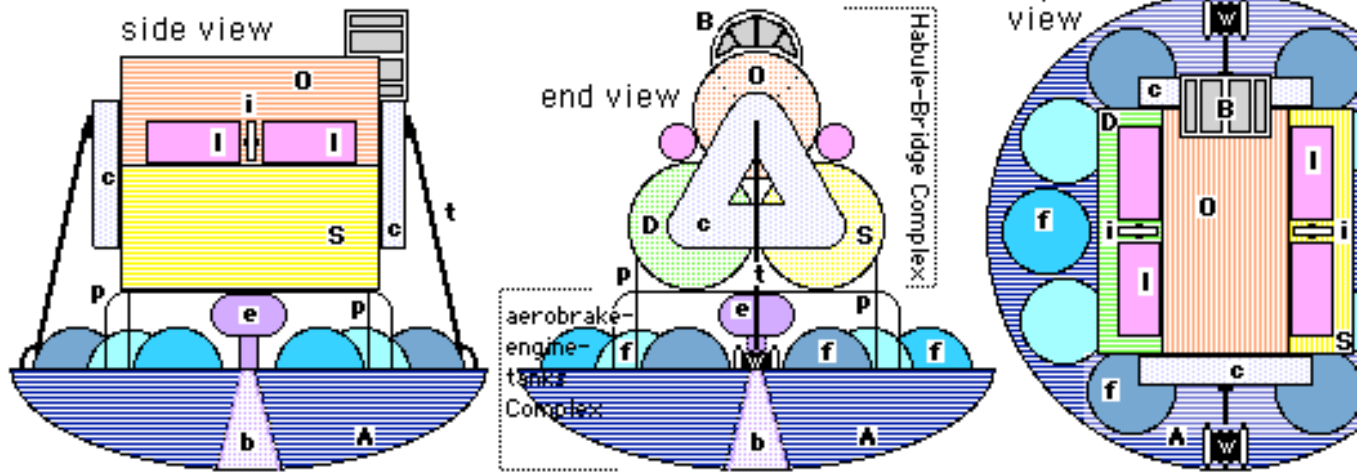
She is a beauty -- once you come to appreciate the elegant efficiency of her design! She looks un-gainly next to the Trans-Atmospheric Columbiad and does not at all remind one of the great spaceliners conjured up by "Sci-Fi" writers.

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 below]

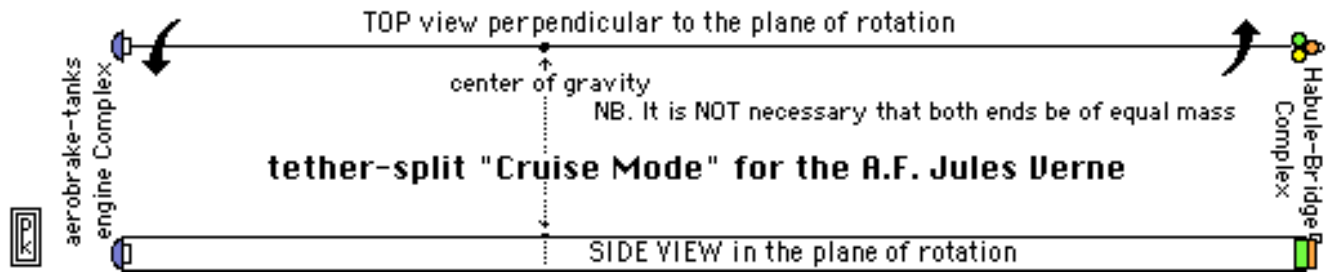
Above the aerobrake, are the engines, fuel tanks, and the umbilical tether-cable reel and winch. On a platform above all this sit two of the three cylindrical habitation units or 'habules' (the initiated simply call them 'cans') built by Occupod and brought up on the Hercules Heavy Lifter. One of the 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 on the way back. (Why the ship cruises sideways you'll see shortly.)

the "A.F. Jules Verne" -- a rough conceptual sketch



- 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 --
I 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.



Letter home continues

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 16:00-23:30 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 24:00-07:30 but may tarry till 09:00. (A surplus of either 'morning' or 'night' people is handled first by volunteers and then if necessary, by a draw.) From 08:00-15:30 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 fiber-glass 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 pre-ordered 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 habule bridge section. Once back together and secure and gravity free, 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 pro-rammed to pay particular attention to pre-specified 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 sight 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. However, 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 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 Mars-like gravity now provided for ambiance, and we begin to come out of our withdrawal. A shipboard 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 deceptively 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 our return, with no other assignment during the past week. Her crew and the staff of the SupraTropicana quiz us with an ill-suppressed hint of envy. Yes, it's been the experience of a lifetime, and with this sneak preview under my belt, I've lost 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**

MMM #22 – February 1989

FIRST EXPORTS

A 1988 SSI Brainstorming Workshop

FIRST EXPORTS 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 trinkets

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

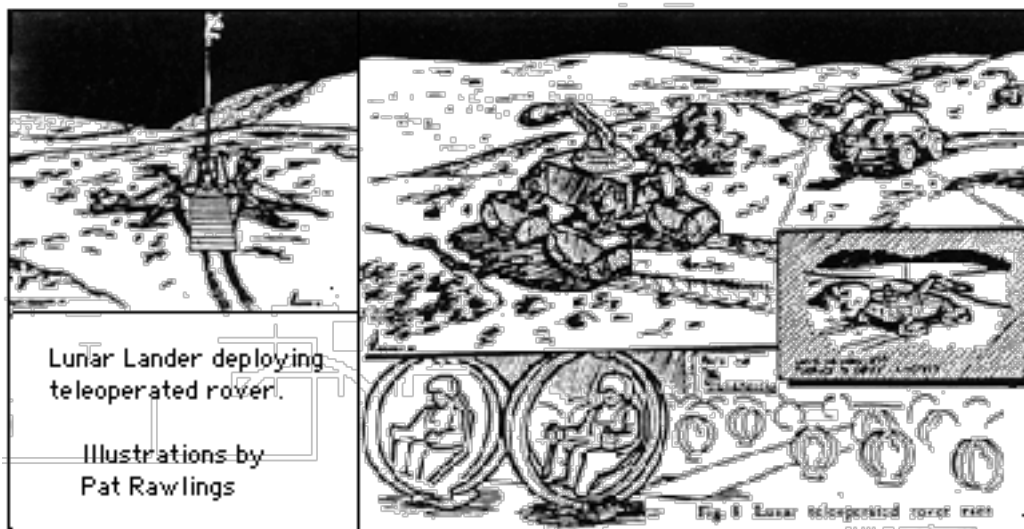
The value of such products on a back-home market is highly speculative and depends almost entirely on demand. The group optimistically hopes for a sustainable demand for such coins and jewelry in the \$300–500 per carat range. [By way of comparison, this is over 100 times higher than the going rates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

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

The third mission would bring up a 3rd generation LOX plant, return fuel and an aerobrake equipped rocket. The mission's purpose would be to demonstrate the profitable return to LEO of a sizeable 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



FIRST SOUVENIR\$

Lessons from Mt. St. Helens

FIRST SOUVENIRS 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 on 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 nonetheless 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.
- **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**

MMM #23 – March 1989

PIONEER 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 micro-meteorite bombardment, a very slow process taking some 10 million years to thoroughly 'garden' the upper first centimeter.

GAS-SCAVENGER

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

GAS SCAVENGER: 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 bombardment¹. 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 moon dust. 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 biosphere, 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 the 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 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 gadget-mobile? 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 under-going a tremendous renaissance in this country, play a major role in illuminating as well as decorating lunar habitats? When 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 announce 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 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, reserve primary building materials for export products, and 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, aluminum, 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 the 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 tailings-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**

* [Subsequently, we actually experimented with such "paints", producing the first Lunar-style painting in September, 1994] – http://www.moonsociety.org/chapters/milwaukee/painting_exp.html

** [Dr. T. D. Lin has since performed successful experiments using steam instead of liquid water, reporting on this work at ISDC 1998.]

MMM #25 – May 1989



LAVA TUBES By Peter Kokh

In the event that the citizen-funded* Lunar Prospector 1 finds no indications of ice deposits in permanently shaded (permashade) 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 sun-shine 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.

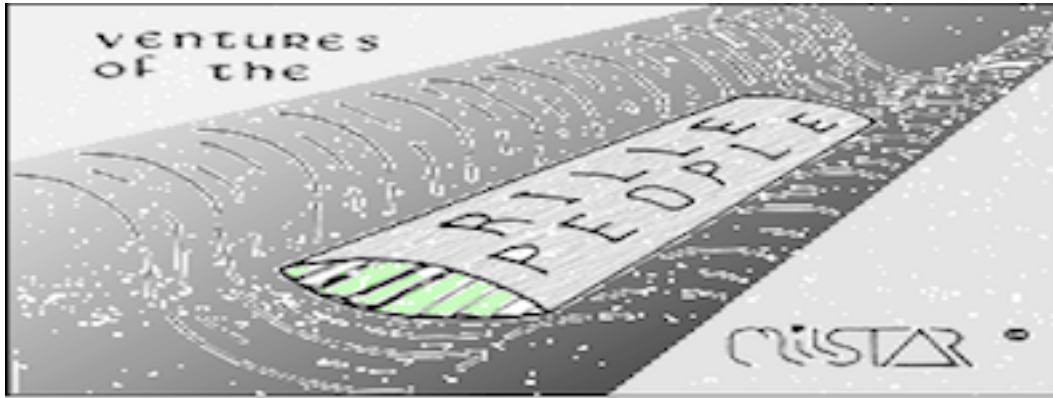
The cost of providing access to an intact lava tube pales in comparison with the cost of providing comparable volume by any other method of base construction. So while at least the first residential and agricultural areas will likely be excavated or built in covered trenches, Lunar Industrial Centers 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.]

MMM #26 – June 1989



At ISDC 1989 in Chicago over the Memorial Day Weekend, the Lunar Reclamation Society “Think Tank” **MiSTAR** 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 Aristarchus.

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 feat 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 Schroeter'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 rilles 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 a lot of excavation plus the hauling of a lot of shielding material up onto the clear span 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

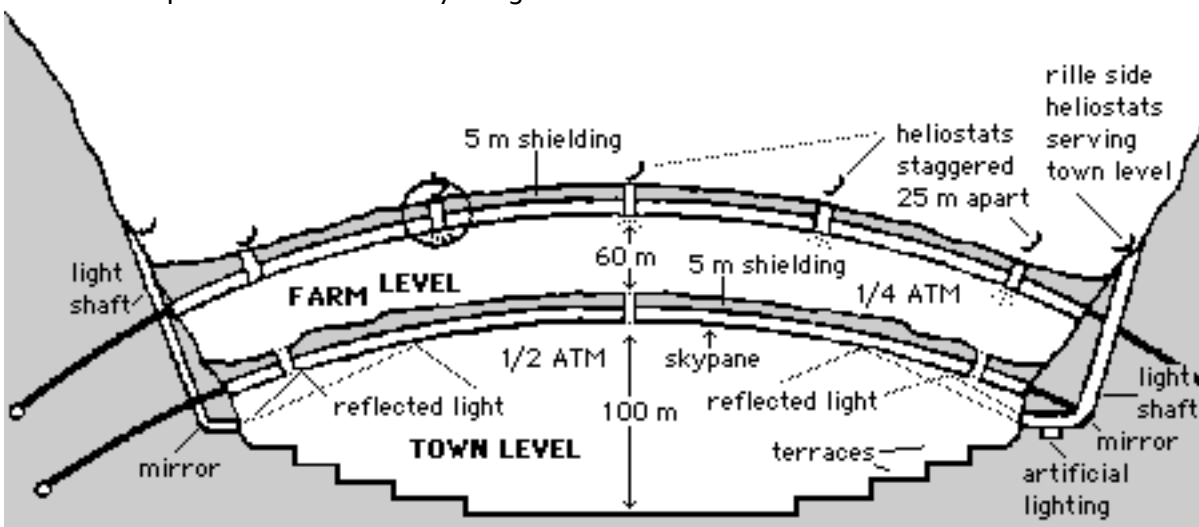
In contrast, rille sites offer pre-excavated sites and the opportunity to pull shielding soil down upon any structure built in the lower portion of the rille. By virtue of its flanks, a rille site offers a vastly greater heat sink [the temperature of the soil below the first couple of meters is steady -4°F = -20°C 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 covered 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



Above: A cross section of the 2-level Rille Bottom Settlement and its basic architecture

So Where is Prinztown, Anyhow?

Prinztown lies in the rille within the red box. The 50 km, 32 mi wide mare-filled crater Prinz is in the foreground



MMM #31 – December 1989

MOONGLOW

MOONGLOW By Peter Kokh [Based in part on a telephone Interview]

"T.L.P." – Transient Lunar Phenomena – could include any visible phenomenon on the Moon that has a fleeting existence, e.g. markings not previously seen and soon gone. In practice, however, the term is used to pigeonhole the hundreds of sightings of short-lived unusual glows, flashes, and (pink or red) colorings that have been observed by many. These happenings, however, have been seen to occur at only about two dozen sites on the Moon, a short list indeed when you consider the thousands of craters and other features covering the nearside alone. The conspicuous crater Aristarchus (brightest spot on the nearside) heads the list in the number of TLP events recorded. A distant second is Alphonsus near the center of the lunar nearside. Copernicus, Tycho, and Proclus are some of the other well known craters on this short list.

In this country there is a small but dedicated band of TLP watchful kept energized by David O. Darling, a member of the American Lunar Society and the Madison Astronomical Society. He lives in Sun Prairie, Wisconsin about ten miles NE of Madison. He became interested in TLP vigilance while observing the Moon during an "Earthshine" event in May of 1979, more than ten years ago. "Earthshine" or "ashen light" happens near the 'New Moon' when only a thin crescent is visible lit by sunshine, but the rest of the disk is visible in a dark ruddy color, the feeble reflection off the Moon's night surface from the nearly 'Full Earth' in its sky. (The Full Earth observed from the Moon is about 60 times as bright as the Full Moon appears to us!) During Dave's May 1979 observation, Aristarchus began to glow so bright, you could pick the crater out with the naked eye. The phenomenon, with ups and downs, lasted about a half hour, a typical lifetime for such events. Dave has watched with dedication ever since.

About two years ago, Dave agreed to head up the TLP Watch program for the American Lunar Society. He has some 14 others in this country who regularly report to him, though some need 'encouragement'. He is looking for additional collaborators. Of greatest help are the strong ties he has established with a group that really has its act together in Great Britain, headed by Peter Foley of the British Astronomical Association. David and Peter are frequently on the phone, trading alerts, endeavoring to verify and corroborate sightings on both sides of the pond.

It doesn't pay to be on the watch for these tantalizing and mysterious events just anytime the Moon is visible, says Dave. Under full illumination by the Sun, any such color and brightness changes would simply be lost in the glare. Thought to be caused by outgassings (Radon so far is the only gas

whose spectrogram has been positively identified – by the Soviets, in Alphonsus), TLP events might well occur at other times without being visually observable.

In fact, however, sightings seem to be more frequent during Earthshine (with favorable phase angles) when the Moon is also halfway between apogee and perigee (hinting that tidal stress trigger). Events also cluster at peak Sun activity (causing outgassings to glow or fluoresce).

TLP watchers gear up for lunar eclipses too. Sudden flashes sometimes occur during eclipses and may be due to electrostatic discharges from the sudden fall in temperature during the event.

As exciting as it is to experience one of these events, the real gratification comes when one's sighting is independently corroborated by others in the TLP network. Recently, Dave saw a darkening in the prominent bright ray crater Proclus (just west of Mare Crisium) and this was corroborated by several others. In the Apollo days, NASA worked closely with L.I.O.N., the Lunar International Observing Network, and a number of Earthbound TLP observations were also witnessed by Apollo astronauts in orbit on the command modules. The astronauts also reported occasional fleeting flashes as they orbited over darkened portions of the lunar farside.

The Soviet spectrographic observation is not the only instrument reading corroborating these visual sightings. The British obtained photometric (light level) verification of the ups and downs in the glow of Aristarchus during the 1989 lunar total eclipse. One of the three canceled Apollo missions had been targeted to put down in Aristarchus. It would have been equipped to chemically analyze any outgassings that took place during its stay and after, for the life of the instruments. Of the three could-beens, this was surely the most tragic loss.

It is rather interesting to speculate whether besides radon, other more economically useful gases might be involved, possibly bottled up in large reserves. The Moon itself is extremely poor in easily gasified volatile elements, and finds of gas reserves that had collected out of the molten magma below, and had worked their way up through crustal cracks towards the surface, could make a big difference in the pace of lunar development. Radon itself is not an original endowment, but comes from the slow radioactive decay of thorium and uranium, both of which are well represented in the lunar crust.

Even though the rocks and soil are 40–45% oxygen locked in chemical combination in various minerals, the Moon is still under-oxidized. The telltale clue here is that there is much unoxidized pure iron (not ore) in the form of fine particles in the loose soil, free for the gathering with a good magnet. This could never happen on Earth. And that portion of iron which is oxidized as ore, is ferrous (one atom of oxygen to one of iron) not ferric (three atoms of oxygen to two of iron – the usual case here). Thus carbon dioxide, a major component of terrestrial volcanic gasses, is far less likely on the Moon than carbon monoxide. But economically tapable pockets of CO would be very important as a source of carbon which might otherwise have to be imported at greater expense.

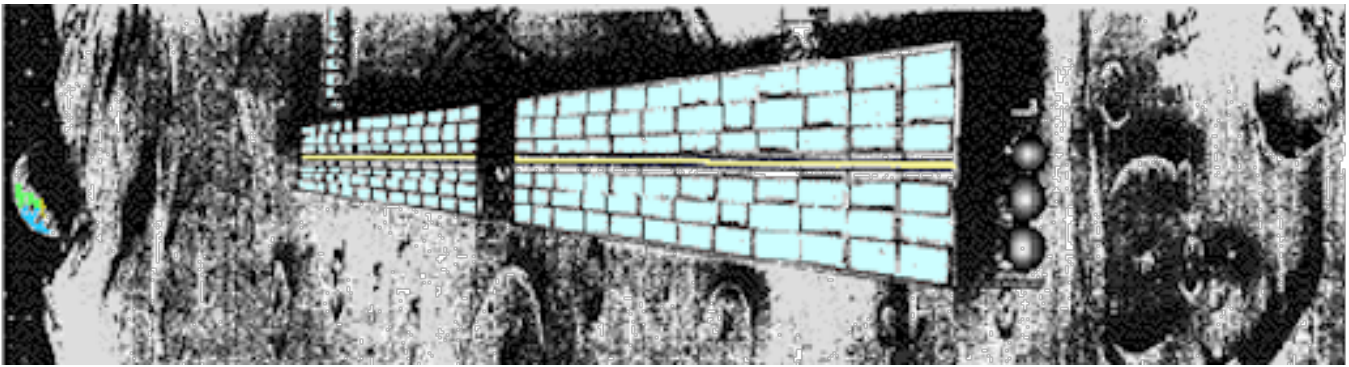
Pros leave the patient and time-consuming TLP watch to amateurs, but this is not because they are disinterested. Darling keeps in touch with Dr. Cameron at U. of Colorado's Astronomy Dept. But the UC telescopes are usually booked up, unavailable for sighting confirmation.

* Darling edits and distributes his newsletter "MOONGLOW" free to a short list of persons truly dedicated to vigilant observation. Anyone interested in participating in this work can link up by contacting David O. Darling.at: 416 West Wilson St., Sun Prairie, WI 53590]

MMM #37 - July 1990

RAMADAS

RAMADAS



Above: a "Ramada" (Ra•MAH•da): Spanish, a free-standing canopy providing shade from the sun, common in U.S. southwest cf. Ramada Inn. Illustration © 1990, Milwaukee artist Dan Moynahan.

"YARD" AND WORKSITE CANOPIES FOR LUNAR OUTPOSTS

Artwork by Dan Moynihan – Article By Peter Kokh

Examine a picture of an Antarctic Base, and you will see a cluster of main buildings awash in an unplanned, unkempt cluttering of fuel tanks, stockpiles of supplies, new equipment not yet installed and old equipment already retired, trash dumps and so on. Base architects have a tradition of leaving to afterthought the siting of necessary external paraphernalia, the things that make base operations work. Nor is such an unsightly hodgepodge of land use expediciencies the only result. Since the realities of base operations were not taken into account, as only individual structures rather than integral functioning of the base as a whole – or likely patterns of growth and evolution – received attention, it is an inevitable result that such sloppy installations function rather less efficiently and less safely than they might.

The sketches available of various Moon Base designs, be they the product of NASA think tanks or of outside sources, share this ivory tower penchant for neglecting patterns of likely land use in the immediate vicinity, in the front and back "yards" of principal base structures.

It is inevitable in any Lunar Base operations scenario, that an appreciable portion of routine "out-vac" EVA activity will take place in a few concentrated areas, especially the immediate vicinity of the Base itself, and of its component structures and facilities. There should be a very thorough effort to identify and categorize the types of activities involved and the intensity of use of these "yard" spaces.

Current planning and design provisions make no distinction between those EVA activities on the base doorstep and those spacesuits-required activities at some distance from camp. However, the relatively high intensity of usage of selected close-in areas for storage, staging, repairs, or other repetitive outdoors housekeeping tasks, offers us an opportunity to make such routine activities both safer and easier.

By designing lightweight, modular, and easily deployable work canopies or "ramadas" strong enough to hold a few centimeters of regolith insulation blown on top, Lunar Base architects can provide built-in cosmic ray, ultraviolet, and micrometeorite protection for these high use activity areas. ["Ramada" is a Spanish word common throughout our treeless plains and desert areas for the shade-providing shelters at roadside rest stops.] Providing ramadas will allow those working in such sheltered areas, while still exposed to vacuum, to wear lightweight more comfortable pressure suits. Under such improved conditions, those working outdoors could put in more hours with significantly less fatigue, with lessened vulnerability to random micrometeorites, and with reduced cumulative radiation exposure.

Such ramadas might be attached to various base structures themselves, in an analogy to awnings and lean-to sheds, or stand free but adjacent to them. They could cover an area continuously or make use of overlapping panels to allow some reflected sunlight to ricochet between top and bottom surfaces into the working spaces below.

Those whose assignments take them beyond such protected yard areas will still require the heavier more cumbersome hard suits. For some such cases it may be possible to design mobile or "re-deployable" ramadas to use at temporary sites of heavy outdoor activity such as can be expected in the field at prospecting sites or with the time-consuming installation of scientific equipment, solar arrays etc.

Kevlar fabric slung over frames of aluminum poles, all brought from Earth, could form the earliest ramadas. In the light "sixthweight" of the Moon, such fabric would be more than strong enough to support an overburden-load of several inches of loose regolith shielding. As Lunar manufacturing develops, glass-glass composite panels covering glass-glass composite lightweight space-frames and pylons, all manufactured on site, could fairly early on become the standard means of providing safe workspaces sheltered from the avoidable "elements" that buffet the exposed Lunar surface.

We began this article by pointing to a general unsightliness that has come to be characteristic of this country's Antarctic bases. While a strategy of careful management of high-use yard space, including the use of ramadas, would clean up much of this clutter, on the Moon as well as in Antarctica, that is certainly not its principal merit. The unsightliness, as much as it grates, is but a symptom of the deeper ill of lackadaisical management of base operations. It betrays an attitude which is of one piece with that same carelessness which breeds accidents, both mechanical and human.

Most will accept that we cannot tolerate the expense of mismanagement on the Moon. Part of good base management will consist in providing the safest possible routine working conditions. The added cost of bringing along the materials to erect ramadas over those highest-use outdoor areas around the base will be well justified.

Next time you see an artist's depiction of a Moon Base, whether it comes from NASA, the Lunar & Planetary Institute, SSI or Eagle Engineering, ask yourself "what's wrong with this picture?" If the grounds look neat and uncluttered all without ramadas, the rendering will clearly be more akin to science fantasy than science fact.

If ramadas are essential facilities for Lunar bases, no matter how absent from base concepts currently in vogue, then a national competition to come up with some good design options will be in order. Such a competition should have three categories:

- (1) For first generation bases, the most economical use of imported material; per square meter sheltered;
- (2) For next generation bases, early practical use of building-materials made on site; and
- (3) Mobile and/or redeployable ramadas for use in the field. Prize money to entice participation could come from traditional sources such as aerospace contractors, but also from materials industries who wanted to promote the use of their products e.g. Aluminum, Kevlar, Glass, and Steel, or from construction firms. **MMM**

[This article is an expansion of an abstract sent to AIAA in response to its solicitation of ideas for Moon/Mars Missions & Bases. Thanks to Michael J. Mackowski of St. Louis Space Frontier Society for alerting MMM to this opportunity.]



BUTT-SAVERS IN THE OUT-VAC

FLARE SHEDS By Peter Kokh

[For a related article, see "WEATHER," MMM # 6 JUN 87, republished in MMM Classic #1]

The Sun does not rotate integrally as would a solid-surfaced body. We can clock its rotation by watching sunspots, slightly cooler areas that look black only in comparison, slowly transit from west to east over a two week period. Spots nearer the equator are carried across the face more quickly than those near the poles, marking one rotation in about 25 days, compared to 28-some nearer the poles, and as slow as 36 days at the poles themselves.

Keep in mind that sunspots, occurring in pairs, mark places where intense magnetic fields project from the surface, and it becomes clear that the Sun's overall magnetic field must become ever more tortuously twisted and kinked with each differential rotation until the pattern finally can be maintained

no more. Such a crescendo is eleven years a-building. At the end of the cycle, the magnetic polarity reverses, so that the overall pattern repeats every 22 years.

Solar flares might be seen as the bursting of solar-energy "dams" maintained by great magnetic forces within these sun spots. As the dam bursts, a flood-surge of energetic particles heads out from the Sun at an appreciable fraction of the speed of light. Light takes $8 \frac{1}{3}$ minutes to span the distance between the Sun and Earth (= 93 million miles = 150 million km = 1 Astronomical Unit) so when a flare is spotted (if anyone, anything, is watching!) we have only a few moments before the deadly storm hits. For the associated X-rays advancing at light-speed, the only warning possible is a means of predicting such eruptions.

On Earth we are sheltered from the full fury of such lethal solar flares first by the Van Allen radiation belts maintained by the Earth's own magnetic field, and then by our atmospheric blanket. Nonetheless, enough energy some times gets through to disrupt radio communications for hours, even cause massive power outages by inducing current surges in transformers and transmission lines. Though the inconvenience for us is mild in our protected cocoon, and while they cause spectacularly beautiful auroras, we can be grateful that flare seasons come 11 years apart.

The most intense portion of a flare onslaught can be over in just minutes or last a few hours. Beyond the Van Allen Belts, the need for shelter is immediately pressing. Flares can occur in clusters and single flares can have the energy of hundreds of millions of hydrogen bombs. The direction the torrent takes is random, depending on the location of the source spot on the solar surface.

Unless we are to limit our activities on the Moon and throughout space in general, to quiet-Sun years, two things must receive priority attention:

1. Developing a Flare Early Warning system
2. Developing a network of storm shelters within reach.

The first need is touched on briefly in the earlier MMM article cited above. The second requires multiple strategies. On route to Mars, we can put all the fuel and cargo and equipment sunward of the passenger cabin (the "P.O.S.H." strategy: Passengers Outfacing, Sun-facing Hold). Coming home with empty holds and tanks presents a more stubborn problem. But here we want to highlight situations on the lunar surface.

Lunar bases, habitats, factories, and whole settlements will be sufficiently protected by the same 3-4 meter thick overburden of loose or bagged regolith shielding that shelters them from cosmic rays and micro-meteorites. Surface activities in the immediate neighborhood of such sites should present no problem even in high flare season. But in time an outpost or settlement will be joined by others as the lunar beachhead transforms into a more "world-like" SET of human places. How do we protect those traveling between such protected sites?

Surface vehicles can be designed top heavy with batteries, fuel cells, cargo and other heavy equipment on top - that's sound practice anyway, and the center of gravity problem can be handled by longer wheelbases and wider tracks - no problem when the cost of real-estate and right-of-ways is moot. While these measures will reduce routine exposure to other hazards, they may be less than adequate during solar flares, especially when the Sun is at a low angle over the horizon. Ports in the storm will be welcome.



FRINGE BENEFITS OF INTENSE LUNAR SUNSHINE

SOLAR WEATHER By Peter Kokh

Most of the pluses of cloud-free access to the undiminished strength of sunlight on the Moon are too obvious to need listing. The key words: heat, electric power, light, photosynthesis. On several occasions we've also mentioned a solar benefit easily overlooked: the considerable endowment of gases adsorbed to regolith fines (pulverized upper soil blanket) from four eons (billions of years) of bombardment by the weak but incessant Solar Wind.

["Helium-3" & "Gas Scavenger" in MMM # 23 Mar '89 - republished in MMM Classics #3]

In this writer's philosophy, anything whatsoever has only assets. Apparent liabilities are just that, appearances things have when one's outlook isn't right: when our knowledge is incomplete, our assessment immature, our attitude is not quite "game."

The usually cited liabilities of the Sun's unbridled stellar fury as it lashes the Moon are these: intense raw ultraviolet radiation and "fortunately rare" deadly blizzards of ionized particles traveling just below the speed of light, originating in solar flares. Our bias suspects both of being assets in disguise.

Might we not quit brooding about the dangers of UV exposure for naked flesh and plant matter, long enough to investigate whether or not this area of the solar spectrum has any potential as an industrial tool? Surely there is incentive enough to pursue the question!

For there is a seemingly endless litany of chemical and industrial processes routinely used on Earth, often with unwelcome side-effects, that do not lend themselves at all to lunar application. Either they involve materials that are too expensive to make available on the Moon, or they would soon be lethal in the unforgiving, tightly closed, quickly cycling mini biospheres we'll need to cradle our existence on our barren neighbor. Given these strictures on our activities, discovery of more Moon-appropriate forms of processing would be rather welcome.

On Earth we're addicted to "improving" and/or "disguising" surfaces of various materials with coatings and/or chemical treatments that would be taboo for one reason or another on the Moon. Looking for alternatives, we might ask what would be the effect on various alloys, types of glass and ceramics etc. of various lengths of exposure to full-spectrum ultraviolet? We have no idea, but shouldn't someone endeavor to find out? (Full-spectrum UV is not yet naturally available on Earth but give the Ozone hole time to grow!)

Through the use of suitable resists or stencil overlays, could some types of glass and some alloys be etched and/or textured? If so, could this become an art and craft method as well as a manufacturing process? If satisfactory fiberglass papers or scrim can be developed, could we print-impregnate this with oxides that would "develop" given raw-UV exposure?

Perhaps these ideas are farfetched idle musings of an armchair chemist. But we would be sorely disillusioned if some happily serendipitous results didn't come out of an honestly far-ranging set of experiments. Will the tests on the LDEF (Long Duration Exposure Facility) finally retrieved this past December by the Space shuttle Columbia, carry useful clues? Undoubtedly six years of raw-UV exposure has done its work on the LDEF trays, but it may be difficult, if possible at all, to sort out these various effects from the smothering and masking corrosion expected from orbit-altitude atomic oxygen.

We have already suggested [MMM # 31 Dec '89 "Ventures of the Rille People" Part V.B. Hydroelectric Storage System?] that the well known germicidal and bactericidal effects of raw-UV be put to work in waste water treatment. (Glass filters out UV but quartz panes let it pass through.) Raw ultraviolet may also play a role in food processing and preparation. Its tissue-destroying ability might be harnessed as a fine-honed tool in various other ways such as "sun"-printing cotton, leather, and jewelry woods. Raw ultraviolet can be reproduced in Earthside labs and, with proper safety precautions, the fun of exploring such possibilities can begin now.

With so much of today's sophisticated processing techniques unsuitable for use in lunar conditions, the settler economy will need all the help it can get. Investigating the effects of raw full-spectrum ultraviolet on the likely stable of lunar materials would be a good start. The opportunity to put solar flares to work will be quite sporadic. But there will be ways to turn that liability into an asset also.

MMM

MOON MINING & COMMON ECO-SENSE

By Peter Kokh

The multi-thousand-year-long record of human mining activities on our home planet will surely be enough to convince even the most bribe-prone galactic bureaucrat to deny us required permits to extend such resource extraction efforts off-planet. In default of such red tape, it is left up to us to judge and police ourselves.

With mines come huge ugly piles of useless barren tailings and scarred landscapes slow to heal, streams poisoned with acid run-off, and legions of workers with dust-racked lungs. The record gives pause to those considering opening up pristine eco-vulnerable Antarctica for development of its legen-

dary mineral wealth. Should it not also give pause to those who look with such high expectations to the plains and rolling highlands of our serene gray neighbor, the Moon?

The salient points to remember are these:

- (1) The Moon's mineral endowment has been minimally differentiated or locally concentrated and is thus distributed rather homogeneously, by Earth comparisons, in ores that are extremely poor by our standards. There will be no reason to fight over deposits or jump another's claim.
- (2) There is no reason to believe that richer deposits lie buried deep beneath the already pulverized regolith blanket that covers the entire surface to a depth of some 2–5 meters. In effect, countless ancient meteorites by their bombardment have already "pre-mined" the surface for us. There is no need for open pit mining.
- (3) As to what does lie deeper, the central peaks of the larger craters represent upthrust material from several kilometers below – sample and source enough should we need it. There will be no need to deep tunnel the Moon.
- (4) In the absence of atmosphere, any and all dust 'kicked-up' by our various activities, has nothing to suspend it above the surface, and is quickly purged from the near-surface vacuum by the Moon's light but effective 1/6th gravity.
- (5) Tailings, the unwanted residue after resource extraction, will be visibly indistinguishable from the source material. Tailing mounds will blend in with the moonscape, and if preferable, can be raked back over the surface. The only clue to an area's having been mined will be a telltale absence of minor craterlets. Tailings should usually be minimal, nonetheless, since more than one resource will be extracted leaving little more than the proverbial squeal of the pig.
[See "Tailings" in MMM # 23 March '89 – republished in MMM Classics #3]
- (6) Fluids and gases used in the extraction process such as water, hydrogen, hydrofluoric acid, chlorine etc. must be brought from Earth at great expense. So resource extraction cannot possibly be accomplished economically unless ways are found to recover and recycle these reagents almost totally (read 99%). There will be no mass leachate drainage into the environment.
- (7) Even in the case of accidental spills of reagent leachings, there is no lunar ground water to pollute or spread the problem. Spills will remain localized and it will be an economic imperative to recover as much as possible. (
- (8) Miners, if you can call them that, will not be breathing atmosphere in contact with the regolith they are processing. Health concerns will instead focus on minimizing accidents and exposure to cosmic rays and rare solar flares.
- (9) As to housekeeping activities of miners themselves in their shielded habitat warrens, they too must recycle and conserve religiously [see "Saving Money on food in Space" – elsewhere in this issue]. They will assuredly be acutely aware that living immediately "downwind" and "downstream" of themselves in cradling mini-biospheres leaves scant room for eco-carelessness.

As long as private enterprise – carrying the baggage of the almighty "bottom line" – is the agent in question, you can rest assured that sheer economic necessity will work mightily to prevent 'eco-nonsense' on the Moon. The real danger would come with government leadership and its deferrable accountability.

When you hear or read someone express alarm at prospects for developing the Moon, remember these points. A good response with this as with any challenge: "That's just what I used to think – until I looked into the matter further!"

MMM

MMM #39 – October 1990

MOON MINING & ENGINEERING REALITIES

By Peter Kokh

In an article in the June 1990 issue of the **Engineering and Mining Journal** with the title

"Moon Mining: should we boldly mine where no one has ever mined before?"

Earl C. Herkenhoff, P.E. raises several points about the very logic of moon-mining. His tone is blatantly hostile.

The writer's principal point is that (to his knowledge) our survey of the Moon's mineral wealth is so incomplete that it is highly premature to be discussing what we can or cannot extract from it, and certainly premature to be spending hard scarce cash on studies as to how to go about doing it.

Our response is that while admittedly our mineralogical survey is far from complete, the wide equatorial swath 'read' by orbiting gamma ray spectrometers on board Apollo Command Modules the last three missions, coupled with the six widely scattered diverse surface sites actually sampled by our astronauts and the three additional sites sampled by the automated Soviet sample-retrieving missions, gives us high confidence that what we've seen and sampled is representative of the Moon at large.

Herkenhoff insults NASA geologists and their carefully supervised astronaut proxies when he speaks scornfully of "only a few pounds of $\sqrt{\text{ "grab samples" "snatched" from the surface of the Moon } \sqrt{\text{ at only "a tiny spot" on the surface where the landing craft was set down.}}$ "

It's clear that the writer hasn't gone even the first mile in trying to objectively understand what we were trying to accomplish during Apollo.

The granted exception to this is the absence of sampling and orbital readings near the lunar poles leaves open the possibility that permashade cold traps in deep near-pole craters may contain volatile resources which have been ruled out elsewhere. On this very point, vis-a-vis the possibility of finding water, the writer betrays his shallow study of published lunar findings by speculating that more thorough prospecting might find hydrates as fixed water in igneous rocks. To the contrary, we are now quite certain that the Moon formed hot and dry and that none of its volcanoes or fissures spouted any steam and that its great lava outpourings were also quite dry.

The writer shoots his respectability in the foot when on the one hand he complains that our exploration has not been thorough enough, and on the other he states correctly that the Moon is 'unlikely to contain minerals that have been concentrated by magmatic segregation'. When he states that 'it is a safe bet that most minerals are complex silicates' he isn't telling us anything that we don't already know quite well.

He also shows the shallowness of his science background when he doubts out loud how we can be so sure that Solar-Wind-derived Helium-3 is more than a local quirk in the few tiny soil samples studied. Surely there is no mechanism by which the Solar Wind could have deposited its largess in anything but an indiscriminate way!

Herkenhoff complains that established mining companies have not been consulted about mining methods – after he has already slipped and told us that they wouldn't dream of trying to extract anything useful from such miserably low grade ores. "Even on Earth, process hydro-metallurgists would flinch at such an assignment."

In point of fact, established companies have been too busy getting wealthy off of Earth's much richer ores to have bothered to accumulate any know-how that might apply to the situation facing us on the Moon. What would be the point in listening to those whose predictable broken-record message is "it can't be done"? We have no choice but to seek out rebels willing to try something new.

He points to the difficulty miners will face in working in vacuum and without abundant water – surely not news to us! We have to pioneer not only whole new chemical extraction processes but engineer new ways of handling the raw materials involved. You have to grant him a sharp touché', however, when he asks how we can ever hope to do anything so difficult, when NASA can't seem to get even simple things straight these days.

Certainly no one should underestimate the engineering and chemical processing difficulties ahead of us. Unfortunately, most space advocates betray in their butt-to-the-sofa fixed positions just such a naive grasp of the situation. We have a fearsome amount of homework to do. NASA is not doing it, and NSS seems to assume it will just all fall into place somehow. SSI by itself can only scratch the surface with member-derived funds it has to work with.

Perhaps it is this all too nonchalant cocky conviction that we display in our bold scenarios for the future that encourages this open scorn. Our dreams of the future may turn out to be on target, but if we continue to rely on nothing more than let-George-do-it [i.e. the government] "activism", how will we ever know?

Herkenhoff lists an impressive bibliography. It is mute testimony that he has done his homework with prior bias in search of ammunition. [

Nb. Thanks to R. McNeil of the Willey Ley Space Society, the Chattanooga, Tennessee NSS chapter, for bringing this article to MMM's attention!]

MMM



DAYSPAN By Peter Kokh

For the watchers on the ridge, it begins with an arcing flame of light punctuating the still dark eastern horizon -- part of the solar corona, something that the atmosphere-coddled Earthbound can never see, except during locally exceedingly rare 'total' solar eclipses. The Sun's intense disk is now still below the horizon, but this great prominence announces its imminent arrival onto the moonscape.

Here on the Moon, the Sun rises with great deliberation. From 'first contact' when the first diamond glint of light from the solar surface itself breaches the horizon, until 'last contact' when the entire blazing disk has just cleared, the Sun takes sixty ceremonial minutes to make its entrance. For such is the slowness with which the Moon turns on its axis to bring the Sun into view. (On the fast turning Earth, this show is run through in fast forward so that it amounts to no more than a two minute skit.) Two hours later, the Sun will have cleared the horizon by only a degree. It will not reach the far horizon, 180 degrees away, for another 14 3/4 days, better than two weeks.

But already this first standard day of the new sunrise, there is a noticeable shift in settlement activity and a quickening of its pace. Within a few hours of first light, solar panels and/or solar dishes, and the many sun-tracking, grabbing, and channeling heliostats will have all locked on to its life- and energy-giving rays.

The Sun is both workhorse and taskmaster for the little community. With its return, added electrical power surges online. Solar furnaces melt charges of raw, or refined, regolith for the productions of sundry items from cast basalt, ceramics, glass, and glass-glass composites or Glax™. The concentrated rays are also put to work sintering iron fines scattered abundantly in the loose regolith blanket, and collected with a simple magnet, into assorted useful pieces using powdered metal technology. And either directly through focused heat, or indirectly through electricity, industrial-strength sunshine begins cracking water reserves back into hydrogen and oxygen for use in fuel cells aboard field vehicles and, stockpiled until sunset, for reserve night-span power generation.

"Make hay while the Sun shines!" Not only does the pace of mining, processing, manufacturing, and field activities such as construction, road building, and prospecting, rise dramatically, but so does that of farming and home sunspace gardening. Plants emerge from their 'subsistence diet' of reduced artificial lighting during the nightspan, thrive anew and resume their progress towards eventual harvest. For most of the base personnel or settler population, the tempo of life has significantly accelerated.

More people venture abroad, "out-vac", either for work or just for a welcome change of scenery, excursion vehicles being the popular choice over cumbersome spacesuits. "Selenologists", still lazily called 'geologists' by their chauvinist Earth-tied colleagues, venture out of their labs to collect fresh samples in the field.

Habitats and pressurized common spaces (the "middoors") are flooded with soul-warming sunshine, thanks to the heliostats which filter out both the unwanted heat of the infrared and the harmful fury of the ultraviolet rays. Stained glass and prisms turn sunbeams into a painter's palette and interior and middoor surfaces take on a new glory. Walls, finished with a cheap whitewash of CaO lime or TiO titanium oxide suspended in a waterglass medium of hydrous sodium silicate, make an ideal canvas for these rainbow-bright live paintings. Greenery, its verdant hues more vivid after 'breakfast', completes this characteristic settlement color scheme.

Oases of park space tucked into crannies of the various food-raising areas are thronged during free time. Schoolyard recess is imbued with renewed spirit. Those going to and from work along pressurized passageways lined with carefully chosen plantings seem to smile with a subtle new radiance.

Any ship carrying tourists will arrive while the Sun illuminates the area. Perhaps most of the visitors will stay to experience the full rhythm of settlement life, and depart during the following dayspan some three or four weeks later.

Long forgotten is the ho-hum grudging routine of daybreak on Earth, oft' equated with life before coffee. Here the Sun's glorious presence transforms everything through and through. For the fourteen plus 24-hour days of dayspan, the life of most settlers will be one of especially earnest industriousness. In every field of dayspan-reserved activities, there will be important production goals to meet if these brash settlers are to "set themselves up" for the quite different, but complementary, routine to follow.

MMM

NIGHTSPAN

NIGHTSPAN By Peter Kokh

For the previous two plus weeks, this unlikely pocket of humanity on the Moon has been a beehive of activity, making use of the Sun's heat, its life-giving rays, and its electrical generating potential, to work through the more energy intensive portion of the long list of tasks needed to keep the community going. For total available on-line power will drop measurably as the Sun finally reaches the western horizon.

While the light available on the surface will remain full-strength until the final two minutes, 'down below' the level of redirected sunlight will have begun to taper off the past day or so as heliostats on the surface, even arranged in purposely staggered rows, begin to eclipse one another, cutting off solar access.

Industries dependent on harnessed and concentrated sunlight will have been located to avoid this problem, so they can keep working on full throttle for the full duration of 'sun-up'. Finally, however, the great solar furnaces and turbines will be shut down and the activities they support will stop. Those industries that depend indirectly on abundant electricity generated by solar arrays must likewise phase down. For whether supplied by standby nukes, fuel cells, spinners, or hydroelectric generators (where rille or crater slopes allow the possibility of pumping up water surplus by dayspan to let it fall during the nightspan), the total amount of on-line electrical power will be likely be appreciably reduced for the fortnight to come. Industry after industry will switch gears, taking up now the rather more labor-intensive tasks that it had strategically postponed during dayspan.

Maintenance, repairs, and changeout of equipment; assembly and finishing; packaging for shipment; bookwork and inventory; – for many workers, it will be rather like switching jobs every two weeks. And per-haps that will be a welcome break in the routine, an anticipated and appreciated periodic shot in the arm, an essential element in sustaining personal and communal morale.

Workers who by dayspan crew those industries that do not have a proportionate list of postponable energy-light labor-heavy tasks to keep them busy during nightspan, might shift to quite different company co-owned ventures that are task-lopsided the other way. Unneeded farm workers might move to food-processing duties etcetera. Continuing education, especially in the line of one's work, might be preferentially scheduled for nightspan.

The Sun now set, Lunans, temporary personnel and permanent settlers alike, will find more leisure time for arts and crafts and cottage industry pursuits. Music, dance and other performing arts will vie for attention. Now there may be more time for shopping and flea market barter. Perhaps only necessities will be bought and sold during dayspan when able persons are best occupied building up export inventories to defray import costs, and producing domestic items to reduce import demand.

Fresh new pioneer recruits may have arrived shortly before sundown. This will give them a taste of what dayspan settlement life is like, saving more intensive orientation for the nightspan when extra senior personnel will be freed up from other duties to devote themselves to this task.

The public spaces of the settlement – its mid-door squares, streets, alleys and passageways – might be more crowded during nightspan with people free to linger leisurely and enjoy activities for which there was little time the two hustling weeks before. Such places will come alive with entertainers and soap box orators, artists and craftsmen selling their wares or demonstrating their talents and taking in serviceable but prosaic "issue" items for customizing makeover into items of pride, hucksters selling similar items on commission, second-hand stalls and exchanges for recyclable items, shelves of produce harvested from in-home gardens and specialty jars of preserves put up by enterprising home-canners – you get the idea.

Ambience provided by electric lighting can take several forms. Great electric lamps might use those same sunshine-delivery systems slaved to heliostats during dayspan to provide periods of simulated daylight each nightspan 'day', with subtle mood-setting lighting for nightspan 'nights' (night life and sleep time).

And color? Colored bulbs as well as stained glass diffusers and dividers will be one way to provide a magically cheerful touch. A harvest of neon and other noble gases adsorbed from the Solar Wind to the fines of the Moon's regolith soil blanket, and recovered by heating during the routine soil-moving processes of mining, road building, and construction, could lead to ample and creative use of neon lights. The "Greek Isles" look of the community's middoor and indoor spaces, in which sunlight splashes whitewashed walls accented with luxuriant greenery, will be upstaged now by quite a different enchantment after dark. It seems unlikely that our future Lunans will fear the night!

At last, the end of the long nightspan will draw near, and the final evening meal of nightspan may become a special one in settler homes, filled with anticipation, maybe even ceremony: "Sunrise Eve"!
MMM

Will Lunans mark the days by the Month or by the



THE SUNTH By Peter Kokh

It should be clear from the above pieces that the arrival of sunrise and, a fortnight later, of sunset will radically determine the scheduling of almost every activity within a lunar community beyond eating and sleeping and making love. Given that most Lunan industries and enterprises must stop to shift gears at both sunrise and sunset, it will be of no small benefit to their efficient operation to schedule "weekend" breaks so that they always fall at the same time in relation to these all-transfiguring events. As the Lunar settlement will be "under the gun" to produce enough exports to balance the cost of needed imports, as well as enough domestic goods to minimize that import need, achieving such smooth operation is not a goal to be dismissed.

But here's the rub. Sunsets repeat every 29.5 days (twice every 59 days) or 12 times a year with 11 plus days left over. The Jews and Moslems have such a calendar of "lunar months" (a tautology, when you think of it). But the Romans, while inappropriately keeping the word, altered the "month" so that an even dozen fit in each solar year. For us on Earth, where the really significant repeaters, affecting business cycles as well as agriculture, are the seasons whose onset is determined by our annual orbit around the Sun, quite irrespective of the lunar phase of the moment, the solar "month" (how that grates!) makes sense.

If the word "month" is no longer 'honest' for our calendrical tomes of 28-31 days, neither does it fit the sunrise to sunrise period on the Moon itself. From the viewpoint of one on the Moon, it is the Sun's aspect which is significant. Hence our suggestion [MMM #7 JUL 87, p9 "Calendar"] that the term "sunth" be coined for the purpose. Astronomers use the term lunation, but as this properly refers to the new moon to new moon period (that is, reckoned from local sunrise at 90° East), it is not sufficiently generic, and again inappropriately refers to the Moon, not the Sun (we would accept Lunar Solation).

Back to our question. Will future Lunans mark the days by Earth's months or by the local sunth? Perhaps they will use both calendars side by side, or a special calendar with dual dating. To visitors from Earth, as to those serving temporary tours of duty with no intention of staying for the rest of their lives, the Earth date will be the "real" date, as if our arbitrary notation were some cosmic fact. Even "tory" settlers (those who have made the move in body but not in spirit) will feel reassured by a glance at our familiar Gregorian calendar.

Meanwhile, not only will settlement life totally ignore terrestrial conventions out of practical need, but both exports and imports and the arrival and departure of tourists will pay heed to the local

Sun angle (the time of sunth) rather than to the date on Earth. Business and accounting cycles for Lunan entrepreneurs will follow the march of sunths, not months. Even those businesses on Earth trading with the Moon will need to refer to the lunar calendar (or at the lunar phases shown on most 'normal' calendars) to help determine shipping times.

From the 59 day sunth-pair to a full "lunar" calendar is a big step, however. For adopting a twelve sunth year of 354 days would put Lunans out of synch with Earth. IF they decide that this is not important, they have three basic options. A) they can simply let their 'years' (or 'calendars') advance over Earth years without any attempt to make an adjustment, as does Islam, giving it 33 years to our 32, or B) they can add an intercalary thirteenth sunth every second or third years, as does Judaism, or C) let the differences accumulate and add 7 extra sunths at the end of every 19th year (conveniently, there are precisely 235 new moons every 228 calendar months). If this last option seems far out, it does present a neat opportunity for a once-a-generation built-in period for institutional and cultural review. Those extra seven sunths could be collectively be called "renaissance" or "renewal".

IF keeping in sync with the year as reckoned on Earth is to be desired, sunths could be numbered 1 to 235, rather than named, in a cycle repeated every 19 years, while the year began and ended in lock step with the familiar Earthside cadence.

However the solar year/sunth incongruity is handled, using the sunth to mark the timing of events and activities within the lunar settlement will mean abandoning synchronization with the Sunday through Saturday rhythm so ingrained in us that we assume the day of the week must be a primeval cosmic framework valid in the most distant corner of the universe, even predating it, as some fundamentalists would insist. In fact, not only is the length of the day a purely Earth-local matter of no cosmic significance whatsoever, but the pegging of names to days in a certain suite with a once and for all calibration, is, however traditional, 100% arbitrary. Nonetheless the week, as it has been handed down to us, is the most stubbornly ingrained piece of our "cultural infrastructure", and it has survived all attempts to tamper with it.

Making the switch to sunthtime, if pursued in earnest, will mean pegging 'weekends' to this beat, i.e. an integral 4 weeks per sunth, i.e. no leftover days, with each sunth starting the same day of the week. But in every 59 day sunth-pair there are 3 days more than an even 8 weeks. An adjustment can only be made by making 3 weeks out of every 8, 8 days long instead of 7. If each of these extra days was placed to make a long weekend, and used for all holiday observances, this would provide 18 holidays a year, quite in line with American practice, but in a non-disruptive format. A "leap hour" every six or seven 'weeks' would keep the 59 day rhythm from drifting, as the sunth is some 44 minutes longer than 29 and a half days.

To avoid confusion (Monday on the Moon while it is Wednesday on Earth, at least this week etc.) Lunans will most likely adopt a totally new set of 7(8) names. The previous MMM article alluded to above, has some creative suggestions for the pioneers.

Another major question to be settled is whether all Lunan communities will observe the same weekend schedule, no matter how many 120-wide 'date-zones' they lie apart from one another, or whether local week-ends will fall with local sunrise and sunset. There are strong tradeoffs and they must weigh and choose.

Such a culturally radical switch in timekeeping would neither be to the point on Earth, nor stand as much chance as a snowball in a supernova. However, Lunans will be living in a workaday environment quite unlike anything ever experienced by any Earth bound community to date. For many settlers, the need to declare cultural as well as economic independence from Earth may be strong. In some form or another, Lunans will adopt conventions of time reckoning that pay only loose homage to our week and month. The year will survive, however, not because the Moon shares the Earth's orbital motion around the Sun, but because the two worlds lie in each other's backyard, assuring a high volume of trade and real time communication*.

I think it will be culturally refreshing! – MMM

MMM #44 – April 1991

[Speculation}

ICE CAVES

Possible Unsuspected Cometary ICE Cold Crypts Below the Lunar Surface

ICE CAVES By David A. Dunlop and Peter Kokh

For centuries we've realized that the Moon's surface was desert-dry. The first good telescopes had shown the great dark areas hopefully called "Seas" to be really dry low-lying plains (filled with a dry quick-sand of dust, many wrongfully supposed). We took it for granted that the Moon had formed wet, as had Earth, and that its low gravity was insufficient to hold on to its aboriginal atmosphere so that its waters had been lost to evaporation and ultraviolet disassociation.

The findings of the Apollo missions and follow-up studies of their precious hoard of Lunar Samples told another story. The maria seas were really great sheets of frozen lava with the upper few meters pulverized and gardenized into a dust blanket (the regolith, a feature shared with highland areas). Moreover, nowhere was there to be found any relics or clues of a past wetter epoch. There is no rusted iron. In fact, even with a gross composition of 42-45% oxygen, the Moon seems under-oxidized. For what iron there is, is either FeO, ferrous oxide (a less oxidized state than our common-place Fe₂O₃), or pure iron fines. Nor are there any hydrated minerals or clays, so common on Earth. The Moon had apparently formed hot and dry, quite unlike the Earth, perhaps from vaporized material cast off (but retained in orbit) following a major collision between the forming proto-Earth and a smaller but rival body forming at roughly the same distance from the Sun. Someday we may know the 'rest of the story' but this is our current best solution to the puzzle.

What we have found instead, quite by surprise, is a non-negligible endowment of hydrogen atoms (1 ton in a football field sized area 1 yard deep - far less than in Earth's driest desert sands) adsorbed to the fine particles of the regolith 'top soil', apparently a gift of the Solar Wind which has been softly buffeting the Moon's surface for billions of years.

Some have suggested that volatile elements, otherwise so absent, could have been brought to the Moon by comet impacts, and that some small fraction of the vaporized ices could have migrated to permanently shadowed polar crater and fissure bottoms where they might have frozen out and been preserved cold-trapped ever since. We have always been highly skeptical about the chances for any portion of such ices to have come down to our day intact. Any early endowment from the age of heavy bombardment in the Moon's first half billion years, should have been mostly, if not wholly eroded by cosmic rays and Moon-flanking wisps of Solar Wind, even if permanently shaded from direct sunlight.

And the fact that there is now an appreciable aggregate total area of "permashade" (estimates as high as 250,000 sq mi), thanks to the Moon's minimal axial tilt of 1.5°, does not guarantee that this has always been the case. In fact there is some evidence that when the surface-shaping early bombardment finally tapered off, the Moon was left with a tilt of perhaps 12° or more, tidal forces working inexorably to upright it since. However the never-say-die hopes of some have been pinned on the recent Nemesis Theory, according to which the Sun has an undetected distant "brown dwarf" substellar companion in an eccentric orbit which has mischievously disturbed the Oort Cloud, sending waves of comets plummeting into the inner solar system every 26 million years or so. This theory is now in disfavor, mainly because a brown dwarf in such a remote orbit could not be a stable companion of the Sun over geologic time. And we personally have lam-basted as incredulous the prevailing belief that episodic comet showers originate in our own Oort Cloud in the first place! [MMM #39 OCT 90 p6 "OORT FOAM"].

Yet we ardently support Lunar Prospector, an SSI lunar polar probe designed to settle the issue by scanning polar permashade areas with a gamma ray spectrometer for three reasons. First we can't afford to be wrong, for such ices, if economically recover-able, would be an invaluable resource that could well accelerate Lunar development by decades. Second, a number of lunar development advocates are stuck on the advantages of a polar site for our first, if not our only base. Even if there are significant icefields at the poles, a polar site would at best play an auxiliary role in lunar development, since the poles offer access to highland type minerals only, whereas all the "coastal" sites offering access to both highland and mare type soils are at some distance from the poles. The alleged around-the-sunth availability of sunlight at the poles is exaggerated. A negative finding by Lunar Prospector would discourage such cull de sac planning. Third, most lunar development planners have been slow to take seriously the need to design dry "Xero-" methods of processing and manufacturing, and the negative results we expect from Lunar Prospector may provide the rude awakening needed to spur work on a more realistic track. But don't get us wrong. We'd be delighted to have our expectations shattered by a positive find.

Yet it has occurred to the writers that there is some possibility, indeed an appreciable chance, that vaporized cometary materials have been cold-trapped in places not exposed to the loss mechanisms of cosmic radiation and solar wind gusts. The greatest wave of comet bombardment of the Moon may have been in the formative era. But even in the past 3 plus billion years since the great impact basins were filled with runny lava, an appreciable number of comets (in episodic waves or not) may have impacted the Moon.

The maria are not totally flat, but have a slow gradient, stepped by lava flow fronts, with highest elevations near the source(s) of the magma upwellings. It is in these relatively higher regions of the mare seas that we expect to find lava tubes. Very near-surface lava tubes would have collapsed, and it is probably their relics we see in the many sinuous rilles (like Hadley, visited by Apollo 15). And we see winding 'rows' of rimless sinkholes which would seem to indicate partially intact tubes a bit deeper below the surface. Here and there, a stray comet might have hit the jackpot, crashing through the roof of a lava tube and vaporizing. While perhaps most of the vaporized material would have escaped out of the impact crater, it is possible some fraction fleetingly pressurized the adjacent segments of the lava tube (too much pressure would only blow out the roof) long enough to freeze out as frost on its floor, ceiling, and walls, at a distance where they wouldn't have been heated by the thermal shock of the impact. Down here, there is no exposure to cosmic rays or errant wisps of solar wind.

We may have won the Solar 'Lottery'!

But we'll have to wait to check it out.

If this seems far fetched, it is quantifiably less so than sustained lunar polar permashade cold-trapping. While more total volatiles may have frozen out over the poles, they are likely to have formed only temporary deposits. Frosts in some few 'lucky' lava tubes would remain at least until the end of the Sun's stable main sequence lifetime, several more billion years.

How could we detect such deposits? In the pre-Apollo orbital surveys of the Moon, a radar reflection that seemed to detect a buried layer of water or water-ice was detected over western Mare Crisium (Sea of Crises, the conspicuous isolated round 'eye' of the waxing crescent moon). In the wake of the confirmation of the Moon's generally dehydrated state, this anomalous reading has been explained away as a probable reflection off the ancient basin bottom below the lava sheet, in an area where it should be shallow. Yet similar shallow bottom echoes have not been noticed in other mare areas, even those known to be shallow throughout! At any rate, without 'ground truth' confirmation, such a reading is but a romantic teaser, given our present state of superficial exploration.

The technical feasibility of deep-looking radar is, however, quite real. Improvements on the radar that have revealed ancient river bottoms beneath dry Sahara sands, may someday reveal the existence and whereabouts of many near surface lava tubes in the lunar basalt seas. In our earlier article "Lava Tubes" in MMM # 25 APR 88 p4 [SASE plus 15¢ to our PO Box], we stated our belief that deeper lava tubes may lie in subsequently buried early lava sheets. Many of these may have been later filled and plugged, but some few could remain void. But whatever the case, only near surface tubes could have been entrusted with this gift of the comets. Will such improved deep-looking radar find a few unmistakably ice-walled lava tubes as well as the more common bone-dry ones?

If so, will the frost layers be so diffused and thinned out on the inner surfaces of these voluminous hollow sanctuaries that, scientific treasure trove or not, they won't be economically recoverable? That's a possibility. The history of space development scenarios and speculations has been heavy on overly romantic expectations. Despite the dashing of many naive hopes, from hydrated minerals on the Moon, to lichen covered fields on Mars, the promise of a human-settled inner solar system rooted in the use of extraterrestrial materials, spring-boarding from Earth's ever growing energy thirst, is still concrete enough to keep us planning and scheming ways to work with the grain of nature off planet. Ice encrusted cavernous tubes on the Moon may or may not be found. But if we don't find any, it will be a matter of bad breaks only. Until we've checked our ticket stub, we can't dismiss the not-so-unfavorable odds that we've won this Solar Lottery!

MMM

EARTH-BASED SEARCHES FOR LUNAR LAVATUBES

Writing in **Starseed**, the newsletter of Oregon L5 Society, Oregon Moonbase researcher Thomas L. Billings discusses ways to search out lunar lavatubes. Tube openings are hard to spot by camera un-

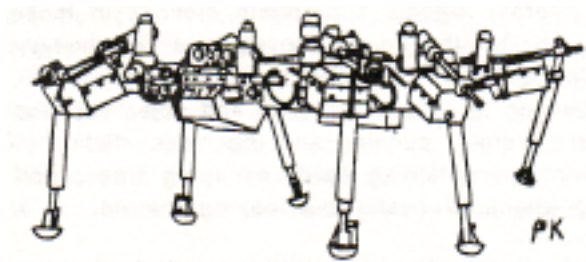
less you are right on top of them. While intelligent lunar base siting will require better orbital mapping than provided for the Apollo landings, the best method may be to look through the rock. The severe dryness of the lunar surface should make this possible for orbiting radar. (Airborne radar has been used successfully to find lava tubes on the big island of Hawaii.)

To provide deep radar imaging, the antenna diameter must be four times the radar wavelength being used. To penetrate deeply enough we'd a wavelength of 5-20 meters, meaning an antenna 20-80 meters across! That's a lot of mass to put into orbit along with the ancillary equipment.

Billings suggests a way out. Readings from a number of smaller antennas in an interferometer array can substitute, synthesizing an image. It will be tricky to do this in orbit, and an intercontinental interferometer is an option Using a 7 meter wavelength, you'd have a 250 meter resolution and a penetration of 70 meters, good enough to detect a convincing sample, given that many tubes are likely to be larger than this.

However, a considerable amount of power will be needed if the signal returning to Earth is to be detectable. Computer algorithms needed to sift signal from noise are getting better. Nor need the search extend beyond a few months, so maybe the expense wouldn't be out of line with the rewards. [Ed.: 1) Would it be practical to intercept that signal in lunar orbit where it'd be stronger? 2) Would Earth-based searches be limited to central nearside?] ∞ ∞ ∞

MMM #45 - May 1991



“Atilla”, a 2nd generation buglike robot

Someday little but bug-smart robots like Attila and its predecessor, Genghis, may roam the storied ocher plains and canyonlands of Mars and other worlds, providing still-Earthbound humans with a lot more exploration data per buck. How far can we take these cute-ugly critters? The limits of “bottom-up” artificial intelligence may be well beyond current forecasts.

ROBO-ANTS

Helpmates on the Space Frontier:
A Constructive Look at the “Bottom-Up” Approach to Artificial Intelligence,
Taking it to its Logical Conclusion.

ROBO-ANTS By Peter Kokh

Several MMM readers have asked if we've been paying attention to work being done on 'robot insects' and the exciting possibilities for their use in prehuman exploration of Mars. Well we have, and frankly, we find the promise greatly underestimated. Here is our report.

At Massachusetts Institute of Technology, MIT, researchers pursuing robotic artificial intelligence have abandoned the conventionally forbiddingly centralized, computer- and software-heavy, “top-down” approach to artificial intelligence patterned after the human nervous system and various problematic theories of how we perceive, think, and decide. Instead, led by Australian-born Rodney Brooks, they are taking their cues and clues from the very different architecture of insect intelligence. Insects are highly successful at tackling complex feats on a routine basis despite their minimalist nervous systems and tiny brains. This is because, in bottom-up fashion, they operate by pyramiding more complex

behaviors on simpler ones starting with simplest autonomous reflexes in individual legs and sense receptors. At each stage, there is no more coordination from above than there has to be to achieve a certain purpose such as walking or climbing or burrowing; and the animal's brain is called into play only when stimuli and the need for appropriate reaction spill over certain threshold levels. By terracing simple steps, activities that would otherwise seem dauntingly complex, are easily handled.

So far, Brooks and his team have built Genghis and a successor, Attila, contrivances which both look suggestively insect-like, and behave in like fashion. They have multiple legs, each with its own autonomous microprocessor, segmented bodies, and stereo eyes. As each leg learns to coordinate with adjacent legs, the 'insect' gains skill in negotiating all sorts of terrain.

The robot-insect is meant to be an 'idiot savant', quite stupid in general, but extremely capable in a narrowly defined field of operation, in a caricature of contemporary human horse-blinded occupational specialization. Unlike today's industrial robots which are designed to perform totally routine operations under identical circumstances over and over again, robo-ants should be able to perform a related suite of operations under widely changing circumstances, be mobile over unprepared terrain, and self-contained.

What's more, these robo-ants can be built relatively small. Given limited payload and cargo capacity, we can land more of the little varmints on Mars (or wherever) and get back a lot more exploration data per buck, sampling more sites. Yet the excitement these prototypes are causing in the space community seems too restrained, conservative, and unimaginative.

Four main points, which we'll explore one by one.

- FIRST, the insect is not the only, nor necessarily the ideal, model of bottom-up intelligence.
- SECOND, we must give correlative attention to sensory apparatus.
- THIRD, there is no need to stop the behavioral pyramiding when we have perfected a functional individual roboant.
- FOURTH, there are even more helpful chores these little beasties might be able to tackle eventually beyond just exploring and collecting samples, and they can be tailored to toil in settings other than the other plains and canyonlands of Mars.

(1) Another Model of Bottom-up Intelligence:

Our first advice for those researchers who want to explore the full range of possibilities that the bottom-up approach offers, and to become fluent in this 'language' and its idioms, is to consider the supreme culmination of individual intelligence in the invertebrate world, the octopus.

This curious creature carries some unfortunate and factitious evolutionary baggage that has kept it trapped at a level far below what its 'alien' architecture should have allowed. To give just two 'for instances',

- (a) The octopus has green copper-based blood (hemocyanin has only 1/20th the oxygen carrying capacity of iron-based hemoglobin, limiting its endurance),
- (b) The female octopus lays swarms of minute eggs, wherefore, lest it eat its own young while they are too small for it to relate to, the female has been naturally selected to die shortly after the eggs are laid.

Despite such handicaps, the octopus is far more capable of intelligently "manipulating" its natural benthic world than the more pelagic dolphin, the usual darling of popular esteem (the sea bottom being a more structured and intelligence-challenging setting than the open sea). In some still future time, it may be possible to correct some of the octopus's evolutionary missteps by genetic engineering (perhaps splicing in bits of genetic material from other mollusks with more desirable traits), and thereby set an altered cephalopod strain back on an upwards course with destiny (sophopods, the wise feet?). But that's the subject for a Sci-Fi novel -- someday.

In the octopus, each tentacle explores rather autonomously, curiously picking up and examining by touch any food-sized object. The tentacle is good at sensing texture, but not shape, and can smell. Only when certain thresholds of stimulation are reached, does a signal go to the animal's brain. Similarly, each tentacle laterally signals appropriate motions in those adjacent, so that the animal moves in a convincingly coordinated fashion. The central brain is like a foreman, giving attention to general direction and objectives (the animal is extremely cunning and ingenious, dedicated and patient, in obtaining food, escaping traps, and preparing sheltered nests) but leaving the details of examination, handling, and locomotion to its tentacles.

Whereas, like 'intelligent' mammals in general, we have a "body image" by which we know where (orientation, direction, posture) our various body parts are (those subject to our discretionary control), the skeletonless octopus seems to have no "body image" at all. And, perhaps as a consequence, it has no 'hand'-eye coordination at all. (This somewhat 'protean' shapelessness gives it the advantage of being able to squeeze its great head through almost any hole or crack big enough to accommodate the thickest parts of its individual tentacles – an enormous strategic advantage.) While the octopus is quite different from the insect, A.I. researchers might do well to study its highly adaptable bottom-up terracing of behaviors and its much greater capacity to learn.

(2) Refining Sensory Apparatus:

Attention has to be given not only to analogs of nervous systems, muscles, and bones, but to the sensory apparatus. Touch, for example, is a catch-all for separate but collocated abilities to sense shape, texture, hardness, wetness, temperature, and weight. If we can design robo-insect foot pads (or individual 'toes'?) with a set of receptors to do all of these, we will be getting off 'on a good foot' (pun intended). A sense of chemical taste should be included, designed to ignore the expected, and notice trace elements in unexpected concentrations. Rather than complex mass spectrometers, this might involve some suite of self-resetting litmus spots. On the other hand, a robo-ant need not have more sensory discrimination capacity than necessary to do the task for which it is designed.

Sight might be offered not only in a front-top-center stereo scanner on a stalk, but perhaps in a task-appropriate 'eyespot' on each foot, or forefoot, with the information not being called to the attention of the central processor and thus merit the gaze of the stereo-scanner, unless its content calls for organized response. In the octopus, the two eyes can cooperate or work separately when the situation allows divided attention. We tend to think two eyes are needed for range-finding (depth-perception) but one bobbing eye does just as well. We are currently at a juvenile level of playful fascination with a digital feast of irrelevant data completely overwhelming efforts at analysis.

Researchers have to find a way to install data-filters that will ignore the non-significant and pick out the reaction-cuing patterns. Perhaps a good way to do this would be to give the eye "zoom" capacity, not just in magnification but in wealth of detail. In other words, a good eye for A.I. purposes, would sense only crude detail, but can "zoom in" in resolution, in spectral coverage (from black and white to special color filters, full colors, infrared, etc. as appropriate), and other vectors (polarization, shading contrasts, brightness, etc. etc.) when something "catches its eye", much like the comic strip hero Superman could "turn on" or "of" his X-ray vision. Thus we need an eye that provides a basic rough view, yet capable of considerable real-time on the spot image enhancement, triggered by the cues. What I would suggest is an underlying wide field of view with low resolution with a scanning focus/zoom device triggered through a series of data filters to 'notice' the unusual and unexpected, stop scanning and fix its gaze, focus, and zoom in for an enhanced view as per above.

A properly designed robo-ant would have specialized legs, perhaps all capable of supporting locomotion, but with some able to concentrate on examination of objects encountered, and others on transporting collectibles to a top-mounted bin or trailing wagon (which could empty its load when full, making piles for later pickup by a more capacious haywagon) or casting small 'obstacles' to the side.

(3) Co-operative Robo-Ants:

At least two dozen separate times in the history of insect evolution, the pyramiding of behavioral functions has spilled over from the individual insect into inherited cooperative social behavior totally beyond the capacities of the isolated creature. The prime examples, and those where the process has gone the farthest, are the social termites, ants, wasps, and bees.

In each of these cases, there is physical polymorphism within the species, that has gone beyond mere sexual differences and given rise to separate "castes" of workers, soldiers, drones, males, females, Queens etc. each of which have specialized built-in equipment and instincts, but together work cooperatively to achieve communal goals. Here there is no personal chain of downward command but rather a collective pyramid of upward input. Given these ample precedents, there is no reason why, once we've really mastered the business of terracing behaviors bottom-up style, that we cannot design our robo-ants in castes such that their specialized behaviors are pyramided to achieve really complex cooperative mission objectives.

We'd first build a Scout class, that explores, reconnoiters, classifies and marks the terrain it moves over. This is what researchers are aiming at now. Sergeants could direct deployment, ensuring full coverage of a work area and act like sheepdogs, keeping units from straying. We can also have Harvesters whose job it is collect objects of interest noticed and tagged by the scouts or perhaps already

placed in convenient 'hay bale' piles for later collection. Refuellers or Rechargers could be on the lookout for stalled ants with an activated out-of-fuel or low-charge blinker. Retrievers could pick up disabled scouts and return them to the main staging area. Mechanics could affect simple repairs of disabled units, refresh their programming, or cannibalize them for parts. Stragglers from other robo-insect collectives could be adopted and reprogrammed. Inspectors could accept or reject (undo?) work not up to their built-in standards. Finally, there could be a queen or mother unit possibly atop a mobile hive-shelter to which individual ants could return at nightfall to conserve heat, to be recharged, to receive updated instructions etc. The mother unit need only recognize progress towards the realization of the collective mission, that is, able to send out a deactivation signal when the job seemed finished, spur on lagging castes, etc.

Communications between units and castes can range from plug-in electronic and/or radio debriefing or reporting to visual clues like variously colored lights flashing in repetitive coded patterns. On Mars communication by sound might also be possible.

(4) Complex Missions for Robo-Ant Collectives:

Now for the rewarding payoff. Once we have mastered the 'language' and idiom of bottom-up artificial smarts, extending it to intercommunicating polymorphic crews, to what use can we put this fluency? Exploration and sample retrieval are only openers, and unimaginative ones at that. Here are some more ambitious missions for our robo-ant teams:

Site preparation and pre-deployment tasks:

- **Remove boulders** from an area, grading and raking, for roads, skidways for craft landing horizontally, and pads for spacecraft landing on their retros.
- **Excavate spaces** for habitat modules, fuel tanks, etc.
- **Collect regolith**, load conveyors, and relay it as a shielding blanket over pre-deployed habitats etc.
- **Identify desirable mineral and rock samples** and pile them up for convenient later retrieval.
- **Do pre-mining sortation**, depositing richer concentrations of sought-after elements as 'leavings'.
- **Sinter or gravelize** 'porch' areas and approaches to minimize dust transport into habitat interiors.
- **Set out tritium marker lights** for roads, landing pads, and in lava tubes and other permashade areas etc.
- **"Primage" lunar regolith** for use as agricultural soil, sifting out ultra fine particles, and transforming glass spherules into zeolites to promote mineral ionization.
- **Spin web mesh** receiver antennas over suitably sized craters for radio astronomy and satellite solar power
- **Survey/map** lava tube complexes on the Moon/Mars.
- **Harvest** thin patchy water-ice deposits in lunar polar permashade not otherwise economically recoverable.
- **Replace damaged panels** in extensive solar arrays.
- **Plug outgassing pores** on comets in preparation for their shepherding to the Earth-Moon vicinity.
- **Locate and map** fissure escape routes for episodes of outgassing on the Moon that we notice as 'TLP' glows (Transient Lunar Phenomena) and mark those where the volume of flow may provide an economic resource

Within habitat-biosphere areas:

- **Tend farms**, trimming dead leaves and stems, tilling, spot-watering, spot-fertilizing, detecting early signs of infestation, picking ripe produce, etc.
- **Sort consumer and industrial recyclables**
- **Clean streets** and other pressurized passageways
- **Change** failed or failing light bulbs and tubes
- **Detect and repair** minor slow air and water leaks
- **In service** of a future Mars terraforming effort:
- **Locate and pre-tap** areas where water-ice permafrost rises closest to the surface.

- **Physically**, and even chemically (where possible with non-consumed catalysts), condition raw soils, sands, and gravels for the introduction of microbial cultures
- **Channelize potential canalways** (identified by orbital altimetry mapping) from polar to equatorial areas; and channelize the ‘saddles’ between neighboring unlinked basins to accelerate development of a mature drainage system in expectation of future rains.

Out Among the Asteroids and Comets

- **Locate, map and presort** and/or pretreat surface-available mineral resources
- **Pre-mine desired resources** on small astrobergs so that only resource-poor tailings need be used as mass driver pellets in coaxing it into a handier orbit
- **Locate intact remnants** of impacting bodies
- **Look for ‘parent-body’** tell-tale signatures
- **Excavate** pressurizable galleries for outposts
- **Produce fuels** from otherwise unpromising fields of volatile-rich materials
- **Make and cache ‘bricks’** and other simple building materials in advance of crew arrival
- **Locate outgasing pores** or vents on comets during their dormant phase
- **Tunnel to the core of comets**, analyzing the material all along the route

All of the above complex activities can be analyzed into a pyramid of simple tasks building on one another, and we should be able to design and program robo-ant teams to handle any of them with a minimum of human supervision or monitoring. In each case, given the higher cost of alternatives, the lower degree of accuracy, consistency, and coverage, and generally wider specification tolerances that bottom-up tasking can achieve may be acceptable. You may think of more applications. Please do send MMM your suggestions!

There are a number of reasonably analogous sites on Earth where such robo-ant teams could be field-tested and given prior experience. The lava tubes of the Oregon Moon Base outside Bend, Craters of the Moon National Monument in Idaho, Antarctica’s Dry Valleys all come to mind. But for many applications a scattering of less unique places including abandoned mines and quarries should serve as well.

“Social” robo-ant co-ops promise to become our indispensable helpmates in opening up the space frontier on the Moon and Mars, on asteroids and dormant comets, and even in free space construction sites, concentrating on tasks of limited complexity in life-hostile surroundings to relieve exploring pioneers and settlers of high-risk drudgery. As such, they could be the Army [Ant] Corps of Engineers of the future.

The work begun at MIT and now catching on elsewhere, is clearly still in its infancy. With a little imagination, there should be Earthside applications aplenty for profits here and now. So perhaps some of you will be motivated to get in on the ground floor. We hope so!

MMM

MMM #47 - July 1991



“Plymouth” Movie storyline highlights key question

In the Zlatoff/Disney/ABC film premiered 5/26, a number of subplots made the movie interesting and kept the action moving. But the central plot was the non-postponable need to decide if the settlement would/could allow the first birth of a human child off Earth. It won’t be real until that happens! In this MMM, we look at Birth & Death, on the Space Frontier.

“PLYMOUTH” TV MOVIE

Focuses on the Community Life of the first Mining Settlement on the Moon.

Aired by ABC Sunday, May 26, 1991

SYNOPSIS from Columbia Pictures Entertainment Inc.

A space shuttle sweeps across the stark lunar horizon, preparing for its descent to the desolate surface below. Once its passengers have safely disembarked, the people of Plymouth, Oregon will have completed the final phase of a five-year relocation plan to a new town – on the Moon.

Plymouth's grizzled mayor, Wendell MacKenzie (Richard Hamilton) is among the last emigrants. On the final leg of their journey, he recalls the events that transformed his family and friends into the first Lunans: the toxic accident that rendered their small logging town uninhabitable; prolonged negotiations with UNIDAC, the global conglomerate responsible for the tragedy; and the unique reparation agreement that was struck.

Besieged with labor and financial troubles at its fledgling Helium-3 lunar mining base, UNIDAC accepts Wendell's proposal: they will construct a permanent, controlled-environment community and relocate some 250 displaced Plymouth residents to run the mining operation that provides Earth with Helium-3, a pollution free energy source.

The arrival of this final shuttle re-unites this tightly-knit community, but could signal the departure of Plymouth's beloved town doctor, Addy Mathewson (Cindy Pickett). A widow with four children, Addy has been living for the past few weeks with the secret knowledge that she is pregnant. If she returns to Earth with the shuttle, the impact of re-entry into the Earth's atmosphere could place the fetus in jeopardy. If she remains, Addy risks the unknown and potentially dangerous consequences of pregnancy in the Moon's one-sixth gravity. Even if her baby is born without complications, the child might never develop the lung capacity or muscle strength it would need to leave the Moon.

Word of Addy's pregnancy spreads through the small lunar town. Plymouth's town council convenes to discuss the problems and choices Addy and the community now face, but the meeting is interrupted by a solar flare alert. All activity is suspended for mass evacuation to sub-lunar radiation shelters.

The first burst of the solar flare has cut off communication with the mining and engineering crew working on the lunar surface. Addy's sixteen-year old son, Jed (Matthew Brown) is one of the stranded crew members -- and there is no way of warning them.

Remembering that an old search module is buried near the crew's location and could provide shelter Gill (Dale Mitkiff) [the UNIDAC employee responsible for Addy's pregnancy and blamed by the townspeople for the crisis this has caused] tears off to commandeer a lunar rover [actually, the first lunar hot rod put together by one of the settlers in his spare time – this is its maiden spin] and race to the work site. As the second stage alert begins, Gil fires up the buggy's rockets and shoots out across the lunar surface.

Meanwhile, Addy's precocious son Eugene (John Thornton) and his newly-arrived friend Simon (Joseph G. Levitt) have gone exploring in the Construction Zone, and are trapped behind a passageway sealed shut in response to the solar flare alarm.

With three minutes left 'til impact, a distraught Addy realizes it will be hours before she knows what has happened to her loved ones.

EDITOR'S COMMENT: How does it all turn out? You'll have to watch if and when it is aired again, or get a homemade videotape. This is the first Sci-Fi movie (made for TV or not) which adopts **the premise that space is a place to get resources to help solve problems on Earth.**

All the right buttons are pushed and the artistic and scientific license is minimal, especially in contrast to everything put on screen prior to Plymouth. At a special screening for a large portion of the 750 attending the International Space Development Conference in San Antonio, the wave of applause and cheering that swept through the audience at the conclusion was verdict enough. This was a crowd weary of Star Wars special effects and monster of the week series, a skeptical crowd which Writer/Director Lee David Zlatoff won over with few reservations.

A movie like this does a lot to correct the unrealistic expectations and gross misconceptions of a public used to Star Wars, Star Trek, Space 1999, and Dr. Who. Chapters might want to get hold of a

videotape of "Plymouth" to show to appropriate audiences. Why not throw a Plymouth Party for a video showing and invite your escapist Sci-Fi friends?

"Plymouth", originally conceived as a series pilot [ABC won't buy the series idea] was finished a year ago and has sat on the shelves all this time, because ABC didn't think people were ready for reality. Space advocates should write ABC and thank them for the airing, comment profusely on how good and useful a picture it is, that it had drama, adventure, personal interest and yet was realistic and educational. Ask them to do a reshooting with much more advance publicity, tell them how much you'd like to see a series based on Plymouth, and ask when you can expect a video release. AND suggest a followup series!

ABC TELEVISION

Attn.: President ABC Entertainment

2040 Avenue of the Stars, 5th floor

Century City, CA 90067

[As of 2005, this film has never been re-aired, nor has it been released on either VHS or DVD. Only bootleg copies home-taped of the TV set exist, in both VHS and DVD formats.]

MMM #48 - September 1991

LOWERING THE THRESHOLD TO LUNAR OCCUPANCY

[Hostels]

[A paper presented at the International Space Development Conference in San Antonio, Texas, May 26, 1991 - here serialized in three parts for MMM]

Online: http://www.moonsociety.org/publications/mmm_papers/hostel_paper1.htm

http://www.moonsociety.org/publications/mmm_papers/hostel_paper2.htm



An Alternate Concept for both First Beachheads and Secondary Outposts

Peter Kokh, Douglas Armstrong, Mark R. Kaehny, and Joseph Suszynski - Lunar Reclamation Society

FOREWORD

Our purpose here is to outline an approach which will promote more timely, and wide ranging human presence on the Moon. In the event that the nation does not commit itself to a fully equipped Lunar Base, the hostel approach described herein could offer a less expensive alternative, a minimal but functional "tended beachhead", a humble yet significant step beyond the Apollo achievement. "Hostel", a term for sheltered sleeping space available to traveling campers, here refers to a pressurized structure offering minimally and inexpensively furnished "Big Dumb Volume" space for the private and communal use of visiting staff.

The concept co-signifies a visiting vehicle to be close-coupled to the hostel for the duration, to provide a complementary "Small Smart Cranny" component. Such a partnership promises to allow hostel and vehicle to function conjointly as an integral, reasonably complete outpost in support of exploration, scientific research, prospecting, and processing experiments, allowing longer, more comfortable stays at minimum expense. In some later time of expanding presence, roadside hostels would facilitate safer, more regular travel between fully equipped distant outposts or settlements across the globe. By not duplicating equipment and facilities that are standard equipment aboard the visiting spacecraft, both the total amount of cargo landed on the Moon and the number of crew EVA hours necessary for establishing a given level of capability, are minimized. Thus the hostel approach has the potential to keep the economic threshold for an initial operational beachhead significantly lower than in other mission paradigms.

Our objectives are four:

1. **Define the logical division of functions between visiting vehicle and shelter**, and how these differ with the particular purpose of the hostel and the prospects for its future
2. **Define design constraints on the visiting vehicle.** Such co-design will be necessary if the potential of the hostel approach is to be realized
3. **Outline logical paths of evolution towards stand alone status**
4. **Examine possible architectures**, whether for prefabrication on Earth or for construction on the Moon using native materials.

During the six Apollo Moon landings, the landing craft did double duty by offering minimal camp shelter on the exposed surface. The Lunar Excursion Module, or LEM, offered hammock-type sleeping and enough floor space to permit two whole steps at a time in a single direction. No one has yet slept in a bed on the Moon, or taken an indoor walk, basic humble everyday functions. As shelter from the elements, this Grumman-built lunar camper protected those within from the incessant soft mist of micrometeorite infall and from the Sun's ultra-violet rays. It actually offered negative protection from cosmic rays or the occasional solar flare, for its thin unshielded hull served as a source of troublesome secondary radiation.

After a lengthy retreat, we now propose to return in style with a fully shielded permanently staffed base complex long on scientific and experimental capability and exploration support, but short on personal and communal space. Several missions would be required to set it up and render it operational. As has proven to be the case with the Space Station, such overreaching skip-step designs must inexorably work to defeat the timeliness of their realization. Is there indeed a middle ground, a reasonable set of design choices which will lower that threshold enough to let us get on with the show within this generation? The hostel paradigm combines the complimentary assets of a relatively inexpensively equipped but more spacious shelter space with base-relevant compact and expensive standard equipment aboard a coupled visiting spacecraft or other vehicle in a synergetic partnership that allows the two to function together as an integral "starter base". The hostel paradigm is offered as a strong statement, even a protest, about the need for more elbowroom in lunar outposts than the more orthodox approaches can affordably provide. But to evaluate the feasibility and practicality of the hostel concept, we have to explore both sides of that special relationship, consider how this dynamic balance may change over time, and suggest how it might be realized in the concrete.

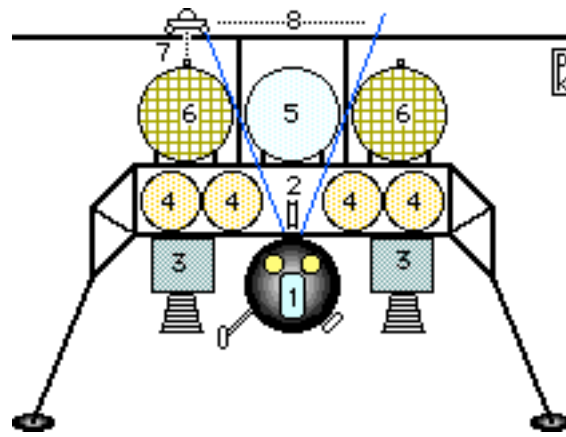
I. THE VISITING "AMPHIBIOUS" VEHICLE

Design Constraints

The design and outfitting of the visiting vehicle is critical to the workability of the hostel concept. The visiting craft must close-connect with the hostel structure if the facilities and equipment it brings are to be used to support any sort of practical routine, and the linked pair are to function together in an integral way. Exercising reasonable precaution, a visiting spacecraft would land a prudent distance from the waiting shelter. Even bridged by some sort of pressurized passageway, the tens or hundreds of meters between would prevent efficient use.

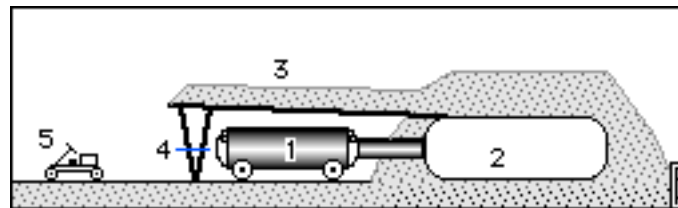
Thus craft must be designed (a) to "taxi" en masse to the porch step of the hostel, or (b)* to lower a conveniently underslung detachable crew compartment, with its relevant equipment, to the surface so that it can separately taxi the distance on a chassis provided for the purpose. We suggest that this is the design choice to make, as it leaves the unneeded and ungainly landing frame, with the rocket engines and primary tankage, sitting on the pad site. When the crew's visit to the hostel is completed in a couple of weeks or months, this mobile cabin would uncouple from the shelter and taxi back to the pad site, reconnecting to the waiting descent/ascent portion for the trip back to LLO or LEO. To highlight the amphibious space/surface character of such a vehicle configuration, we have dubbed it the "frog."

Figure 1: The amphibious "Frog"



- KEY: 1 Frog (detachable mobile crew cabin) wheel on right retracted, wheel on left extended
- 2 Winch to lower/raise frog
- 3 Main rocket engines
- 4 Fuel tanks – 5 Oxidizer tanks – 6 Cargo pods
- 7 Overhead crane/winch for cargo
- 8 Central clear-vision area for top viewport navigation

Figure 2: Generic Sketch of Hostel Concept



Frog vehicle docked/coupled to Hostel under shielded open-vac canopy for duration of crew visit.

- 1 Frog – 2 Hostel – 3 Canopy – 4 EVA airlock – 5 Open-vac rover

Frog vs. Toad

The descent/ ascent stage could also be designed to take off without the crew module, picking up a new one at LLO or LEO. The original crew compartment vehicle would continue to serve as a lunar surface transport. This “toad” version, would require a more rugged chassis, more serviceable engine, and some sort of refueling arrangement. If we are to settle the Moon in a self-leveraging way, “toads” introduced to serve remote outposts, may be the ideal ‘dues-paying’ way of importing the surface craft needed before the settlement is able to self-manufacture its own coaches. Thus, whether the crew’s came through open space or across lunar terrain, the vehicle that actually couples with the hostel structure will be functioning as a surface vehicle at the time.

The frog/toad/coach arriving on site could (1) be designed to hard-dock, in which case it must (a) be able to level, orient, and align itself properly for the task, and (b) be able to either lock or deactivate its suspension, perhaps with retractable legs. (If the suspension were allowed to continue floating, the hard-dock seal would be under continual stress with personnel moving back and forth.) Alternately, the vehicle could (2) be designed to link-up with the shelter via a somewhat flexible and alignment-forgiving, short pressurized vestibular passageway (a) extending from itself to the shelter, or more logically (b) tele-extended from the shelter to itself by a prompt from within the vehicle. There would seem to be engineering, weight, and safety tradeoffs between these hard- and soft-dock options and we do not suggest which would be the more practical in the short run..

[One criticism of our frog concept brought to my attention at the conference was that, as illustrated, it involved a pair of widely separated engines, one to either side of the centrally suspended mobile crew pod, introducing potential instability if either engine had to be shut down for any reason. Our response is simply that there is so much to be gained by using frog-like vehicles – however they be configured – that it is very much worth the trouble to find or develop engineering work-arounds of

this problem feature (e.g. a single top center engine with the exhaust split between pod-flanking exhaust bells). By hook or by crook, there has to be a way! – PK]

Outfitting constraints

To play its part, the coupling vehicle is outfitted so that the capabilities it offers are complementary to those offered by the hostel shelter. The repertoire offered would vary according to the customary length of trip for which the vehicle was designed. The possibilities suggest two general classes, the ‘commuter and the traveler.

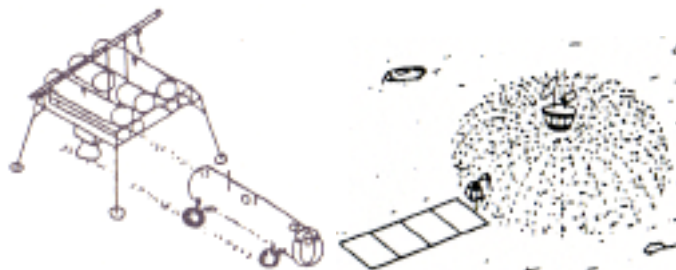
(1). **Commuter class vehicles** would include shuttle craft plying between the lunar surface and either an orbiting depot or a more substantial orbiting mother craft such as an Earth to Moon (or LEO to LLO) ferry. Also fitting the description would be suborbital hopper linking mutually remote lunar sites. In either case the commuting craft is occupied for only a few hours at time. Thus it may not contain berth space, galley (though food stores are likely to be a major part of the cargo), or head, though some emergency-use only arrangements would be a prudent option should the craft go astray or be forced to land far from its destination.

Even here, we have a vehicle which could bring something to a hostel partnership. For both shuttle or hopper will have communications, navigation, and computing equipment which do not need to be duplicated in the hostel. And either will likely have an emergency first aid compartment complete enough to serve the crew in its hostel stay, as well as other emergency survival provisions. Finally, its air recycling equipment (a water recycling capacity is less likely) and ventilation fans, might easily be oversized without too much weight penalty, so as to also serve the hostel space well enough in a close-coupled configuration.

(2). **Traveler class vehicles** would include such landing craft comprised of a shuttle module delivering a “through-cabin” crew-pod transferred from an Earth-Moon (LEO-LLO) ferry. As on the coast to coast Pullman sleeper cars passed on from one railroad to the next in an era now long gone, the crew coming to staff the hostel would ride the same “through-cabin” all the way from LEO, or even all the way from the Earth’s surface.

Also in the cruiser category is the “overland” coach (from an established settlement or full base) designed for trips cross-lunar excursions of a day or more in duration. In either scenario, the visiting craft will contain serviceable if cramped “hot-rack” berth-space that can serve in the hostel-hookup as emergency infirmary beds if isolation or quarantine is called for. And certainly the craft will have at least a minimally equipped galley and head (possibly with shower) as well as a compact entertainment center with some recreational extras. Such more fully equipped vehicles would serve especially well as hostel complements, leaving the hostel to provide what it can offer most economically and efficiently: hard shelter from the cosmic elements, and plenty of elbowroom to serve the less expensive low-tech but space-appreciative aspects of daily life -- private bedrooms and communal areas for dining, gaming, exercising, etc. <<< LRS >>>

MMM #49 – October 1991



The Magic of Symbiosis

Life clings to rocks in the frigid wastes of the arctic Tundra in the form of lichens, a symbiotic partnership of green algae and colorless fungus – neither of which could survive alone. Similarly, little smart “Frog” and big dumb “Hostel” might combine their assets to create a “full-function” lunar base. We examine the magic of this symbiotic relationship in depth in Part II of “HOSTELS” below.

LOWERING THE THRESHOLD TO LUNAR OCCUPANCY



HOSTELS: An Alternate Concept for both First Beachheads and Secondary Outposts

II. THE HOSTEL'S SHARE OF THE WORKLOAD

General Philosophy

Approaching the suggested vehicle–shelter functional partnership from the point of view of the hostel itself, we must keep in mind both the economies to be gained by keeping the shelter as low–tech and inexpensively simple as possible while still serving its purpose, and the competing consideration that we might want it to design it so it can evolve over time into a fully configured autonomous base. The underlying concept of the lunar hostel is that base functions can be physically and spatially separated into two broad types.

(1) Cranny–loving functions. The first includes the compact but expensive equipment that is needed to maintain human existence outside our native biosphere, to maintain the health of the crew, to support the crew's scientific and exploratory research tasks, and to maintain contact with the rest of humanity from which it is physically isolated. The whole evolution of vacuum–worthy craft has been to make such equipment ever more compact and lightweight while ever more functional, productive, and capable. This first category thus principally includes those things that the crew must always have access to, whether it is settled–in on the Moon, or in transit between Earth and Moon, or simply orbiting the Earth.

(2) Room–loving functions. In contrast, there is a second broad category of functions which principally includes those things that are not missed in the short run (and so need not be provided for periods of the order of Earth–Moon transit times or shorter) but are needed over the long term (and thus are ideally provided by durable in–place shelter to be visited for extended periods.

These are the functions which, because we lacked the lifting capacity or out of sheer economic necessity have been at best shoe–horned–in on spacecraft and orbiting stations, but which for personal and group morale and psychological well–being should really be offered on a far less space–stingy basis: honest to goodness personalizable private quarters with ample space to move about, arrange one's personal effects, display (if only for oneself) any personal treasures or hobby–work; pleasant dining, assembly, and meeting space (wardrooms); quiet places for reading; places for shared entertainment or gaming; places for space–hungry exercise routines.

These long–term needs were necessarily ignored on Mercury, Gemini, and Apollo because the space to serve them could not be set aside. Nor have such spaces been more than suggestively and teasingly provided on the Shuttle or even aboard the relatively voluminous Sky–Lab. True, sardine–can packing can be sustained even for months if there is light at the end of the tunnel, as ample submarine experience has demonstrated. Yet it hardly contributes to morale.

More to the point, such elbow–to–elbow jostling may prove to be much less tolerable over any length of time in settings where the outside environment is one of unsurvivable desolation, however magnificent; where a play of sterile grays and blacks, is nowhere relieved with soft and friendly greens and blues; where there is no wildlife to be found at all, not even 'alien'. Space Station planners have endeavored to give some consideration to these needs, exploring design innovations that might make the station's unavoidably cozy spaces more human.

Since on the Moon, the task of maintaining individual and communal morale and mental health will be much more challenging than in low Earth orbit, if there is a way to provide both more generous private and communal space – not just workspace – without undue expense, it should be prioritized. It is our premise in this paper that by not unnecessarily duplicating equipment and facilities already needed aboard the visiting craft to sustain life in space, appreciable dollar and fuel savings can be gained which can be spent to this purpose.

Gray Areas

Before we consider how in the concrete such liberal camp space shelter can be offered (that is, building materials, construction methods, architectures, and deployment options), we wish to consider some gray areas, facilities and outfitting whose proper placement – in the coupled visiting craft or in

the hostel space – might be debated. We did not attempt to reach definitive answers. But in each case we list considerations that seem pertinent.

(1) Communications/computer center: The need for redundant systems is inarguable. But there placement may be a matter for dispute. Accepting that the hostel would never be occupied without a visiting vehicle coupled to it, one might still argue that the various systems aboard the visiting craft necessary to maintain life and contact with metropolitan humanity should be duplicated within the base structure itself as a matter of simple precaution. Here one should keep in mind that spacecraft systems are already by themselves provided redundantly. But the point might still be made that the coupled spacecraft is unshielded and therefore could be knocked out by a rare meteorite of sufficient size. A testy rejoinder would be that anyone that concerned about remote possibilities, doesn't have 'the right stuff' and shouldn't volunteer for such duty.

But accepting the challenge made, we can more constructively reply that it would be possible to offer shielding protection, not to an intact conventional lander, but to the detachable crew-compartment become bus (i.e. the frog or toad), under a shielded but vacuum-exposed carport-like canopy extension of the hostel structure. Such a "ramada" would also shield routine doorstep and porch outside activities: outside vehicle maintenance, storage areas for surplus supplies and discarded items; items awaiting shipment, etc.. But if such sheltered parking space is provided, the vehicle's antenna would be effectively blinded. Therefore the hostel must be equipped with the necessary antenna(s) for joint operation.

(2) Electric Power Generating Capacity: The power systems aboard the docked vehicle will be sufficient to take care of its own needs in transit, probably via fuel cells with a couple of weeks of emergency reserve power at best. While the activities the hostel itself is designed to support within its own confines will consume relatively little power, and even less to run whatever minimal housekeeping equipment, if any, is needed in between visits, we are left with some real challenges.

(a) Compact workstations aboard the vehicle may need more power when the vehicle is parked and functioning as an integral part of the base combo than when it is in transit.

(b) If the landing vehicle does have a modest solar power array, this is most likely to be a part of that apparatus left on the pad. Connected to the detachable crew compartment or frog, such arrays might be effectively disabled if the frog docks with the hostel under-neath a shielding canopy out of sunlight's reach, as recommended.

(c) Nightspan power needs must be taken into consideration, even if these are minimized by apportioning base operations into energy vs. labor-intensive tasks reserved for dayspan and nightspan respectively.

Thus for a stay of any real duration, the location within the integrated base (frog or hostel) where the power is actually consumed becomes irrelevant. The apparatus to generate it and store reserve supplies will be weighty, no matter which path is taken. Therefore principal power generation and reserve storage must be the contribution of the hostel component, with the apparatus necessary a part of the original hostel endowment package. This hostel-provided power system could also electrolyze whatever water that had been generated in the frog's fuel cells en route to the hostel, so that its hydrogen and oxygen fuel reserves were fully replenished for the return trip. Any surplus gas could be stored in shielded tanks outside the hostel as a handy and welcome fuel/water reserve for the next visitation. Under this arrangement, fuel cells aboard the frog, which would go off-line for the duration of the coupling, would be fully available as backup for short routine repairs to the principal system or for 'mayday' emergencies.

(3) Air Quality and Ventilation: Any crew-rated spacecraft is going to have redundant systems serving this need. It would seem that it would be cheaper to oversize these aboard the visiting vehicle so as to handle the extra coupled volume, than to install separate and independent air management systems in the hostel. However, it may be necessary to put complementary equipment in the hostel to dehumidify and sterilize the air within after the crew departs, so that the next crew to visit doesn't walk into a dank and moldy place. An automatic cycle that would dehumidify and then heat the air to perhaps 70° C for a relatively short time would possibly do the trick, allowing the air to stand without further treatment or control until the next visit when a short, perhaps vehicle-assisted procedure would restore the proper humidity, temperature, and ionization level. This still allows the bulk of the equipment needed to treat air currently being used to be housed by the visiting craft.

(4) Thermal Management Systems: This need includes tasks that could be appropriately apportioned between the partner elements. With suitable architectural attention, the hostel could be built and shielded to be thermally stable. Between occupations, the hostel could either be designed so that the interior temperature falls to that of the surrounding soil blanket (-4°F or -20°C). Alternatively, the hostel could be designed to harvest and store heat from dayspan sunlight so as to coast at some higher but still level still on the cool side but from which recovery to (and maintenance of) comfortable room temperatures will be easier and quicker. Most of the activities for which the hostel space is designed to make room should generate little heat. If the coupled vehicle is parked under a shielding canopy, extensive heat rejection arrays for excess heat generated within might likewise be unnecessary.

But if a thermal surplus is expected nonetheless, the radiators indicated would best be a hostel feature, easily integrated with a solar array, or possibly placed on the permanently shaded underside of attached ramada areas. Meanwhile, the control apparatus could be housed in the visiting vehicle if it doesn't require much space, since the vehicle already houses ventilation and air quality apparatus which would have to be integrated with the thermal management system.

(5) EVA Airlock and Open-vac Rover: An air-lock for suited exit onto the surface needs to be a part of any functioning lunar base. For this purpose, if the visiting crew vehicle already has its own EVA airlock as standard equipment in addition to its docking adaptor, as seems likely, this should serve the joint vehicle-hostel operation quite adequately. The hostel need only have a docking adaptor and connecting vestibule with which to interface with the visiting vehicle. Personnel would then exit onto the surface through the coupled vehicle. Again the hostel would not be occupyable without the pressurized vehicle attached, and any contingency which is likely to make the latter unusable or unenterable, is likely to doom the combined base at any rate. In sum an additional airlock as part of the hostel proper, would be an option of definite eventual value but not an immediately pressing need. If not original equipment, such an accessory could be added latter, as part of a docking port extension, as increasing use of the facility and the prospects for its evolution into a fully equipped base warrant. For exploratory sorties to nearby spots of geological interest of resource potential or for recreational change-of-scenery jaunts, a separate unpressurized Apollo-type rover would be carried along by the first vehicle to visit the ready hostel, to be left on site.

(5) Recirculating Water Systems: These, along with waste water treatment equipment are unlikely aboard visiting commuter-class vehicles, but plausible in traveler-class ones for which the hostel concept is properly tailored. If the prospects for the particular hostel to be transformed into a permanently staffed autonomous base are positive, such systems will be an early addition to the hostel's offerings. But at the outset, almost by definition, the vehicle will be wet, the hostel dry. This implies the following:

(a) Toilet and personal hygiene facilities will be offered in any non-commuter type craft, in which case installing additional plumbing and waste treatment facilities in the hostel space from the outset would seem to defeat the purpose. But carry-in-and-leave convenience plumbingless toilets that shunt their wastes to external shaded holding tanks where they will freeze, are to be recommended for placement within the hostel space if they can be designed so as not to need special venting. For the alternative of keeping the wastes sealed within tanks aboard the visiting vehicle, presumably for disposal in space or for return to Earth, would not only add to takeoff weight unnecessarily, but would constitute almost criminal waste of what, on the Moon, will constitute an invaluable exotic volatile-rich resource to be husbanded with care. Even before the onset of lunar agriculture, which could compost such wastes and recycle them so as to enrich the regolith-derived soil, it will cost nothing but storage containers to bank these wastes, inertly frozen, until that day does come. Even if a particular hostel site is not destined to become a full-fledged base or settlement, its stored freeze-stabilized wastes could be collected at any convenient later date and transported to wherever they can be used to enhance on-Moon agriculture.

(b) Food preparation and dining would seem to another task apportionable area: the food preparation, scrap handling and dish washing capability of the vehicle's galley need not be expensively duplicated; relaxed casual dining complete with 'atmosphere', can be cheaply arranged within the hostel's more spacious setting. The vehicle may have a locker for the fresh food supplies it has brought along for the mission. But a pantry for long shelf-life contingency rations would logically be put within the hostel along with a snack bar.

(c) Laundry tasks may also be apportioned. Given the water treatment and recycling facilities on the vehicle, if crew stays were long enough to make laundering desirable or necessary, and if space could be found in the vehicle, that would seem to be the logical choice for washing. Clothes drying

could easily be done anywhere within the hostel, which might even have space enough for hanging items 'out' to dry, if such an option did not burden humidity control. If the planned hostel stay is sufficiently short to make laundering unnecessary, each crew could simply bring in their own fresh clothes and bedding, taking the soiled items with them when they left – in keeping with a recommended leave-as-you-found-it, bring-with/take-with honors code protocol. But alternately, soiled fabrics could be allowed to accumulate in shielded but sterile vacuum outside so that their exotic and precious imported carbon content would remain on the Moon as an endowment, to be reused or recycled in some existing or future settlement. Replacing carbon-rich fabrics from Earth with new goods will be marginally less expensive than bringing soiled items all the way back, then returning them to the Moon cleaned.

(7) Medical Facilities: Medical care presents another gray area. Cabinets of medical supplies and common procedural implements, especially those needed to handle accidental injuries and trauma cases as well as the more common fast-developing transitory ailments, are likely to be standard features of any visiting craft. The hostel, in turn, offers roomy bed-space for patients. This allows any much less generous berth space aboard the coupled vehicle to be pressed into service where isolation or quarantine is advised, even as sealable morgue space if need be.

But expensive, diagnostic equipment, compact or not, with the instruments and medical supplies needed to handle the full range of more plausible eventualities is something that may not be provided at all at first. Such a level of medical capability might be added later, however, and preferably within the hostel itself as the frequency and duration of visits increases. If any of the personnel must be returned to Earth for medical reasons via the coupled vehicle, everyone else must leave as well; for in the coupled vehicle/hostel scenario the hostel, by definition, is not configured to function separately. It will be a principal priority in the evolution of the particular hostel, to minimize the likelihood of such premature abandonment.

(8) Workstations and Laboratories: Provision for geological and mineralogical analyses is a primary design criterion. And the need for facilities to support lunar materials processing feasibility studies will be of increasing importance as the human return to the Moon becomes more earnest. The first relevant consideration is whether the proposed workstation is wet or dry. The second is whether the supported research can be done in a compact space or needs extensive floor/wall space.

The logical division would locate compact testing and analysis work stations, wet or dry, aboard the visiting craft. This would allow convenient changeout and updating of equipment on return visits to Earth or Earth orbit. "Dry" research needing extra space can be provided within the hostel structure proper. "Wet" research or experimentation needing extra space should be examined to see if the wet and dry tasks can be separated by location without too much convenience. If so, the dry part of the operation would have a claim to hostel space conveniently near the docking passageway. The hostel, in turn, would offer inexpensive and liberal sample storage lockers, and sorting and display areas.

But in deciding where to house various workstations, we must also take a more comprehensive look at the mission context of such hostel-stays. If there is more than just one hostel site for a single vehicle to visit, it will indeed require less expensive duplication to provide such space aboard the vehicle, so long as the equipment involved is not particularly massive. If, on the other hand, we are dealing with a single hostel visited by a small fleet of similar vehicles, it would require the least duplication to put such workstations within the hostel structure proper. Again, if each frog is specially equipped to support a particular research agenda that changes with each stay (as has been the pattern with Space Shuttle missions to date), the pendulum swings in the other direction. The question cannot be fully resolved outside of the mission context and the hostel's continuing evolution through use.

If in general, most workstations are in fact built into the visiting vehicle, reserving the hostel principally for off-duty functions, such a segregation of activities would lend itself especially well to shift-scheduling, with on-duty personnel clustered in the vehicle, and off-duty personnel within the hostel. A two shift setup with shared social time might prove the most workable and best for group morale. Whether such a separation of activities by area is practical or not, we suggest that the passageway space, short or long, connecting the two areas of the outpost combo, be designed with sound-buffering in mind. However all such considerations are secondary in deciding where each workstation should be.

(9) Exercise Areas and Equipment: These are best placed according to the nature of the activity in question. While some daily ritual types of exercise need little room and can be performed in a compact exercise area within the vehicle such as the wardroom area, other exercise routines are space-hungry; to provide for these, any portable equipment needed could be brought into the hostel and left there.

The hostel's interior spaces and overall architecture might conceivably be designed and arranged to incorporate a banked peripheral jogging track, or even a "sixthweight" caricature of a bowling lane. A billiards or ping-pong table, even a handball court are imaginable, given enough cheap dumb volume.

(10) Entertainment and Recreation. The visiting craft will doubtless possess its own entertainment console and a modest audiovisual library. Small personal audiovisual consoles would be an inexpensive and welcome feature for the private quarters within the hostel. With ample space, separated communal viewing and listening/reading areas could be provided. Additions to the hostel's audiovisual library, extensive reading materials on CD-ROM, [written before the arrival of DVD technology] even a modest collection of low-weight art pieces, could be carried in and contributed by each new visiting crew, continually enriching the cumulative samples of Earth culture available on the Moon.

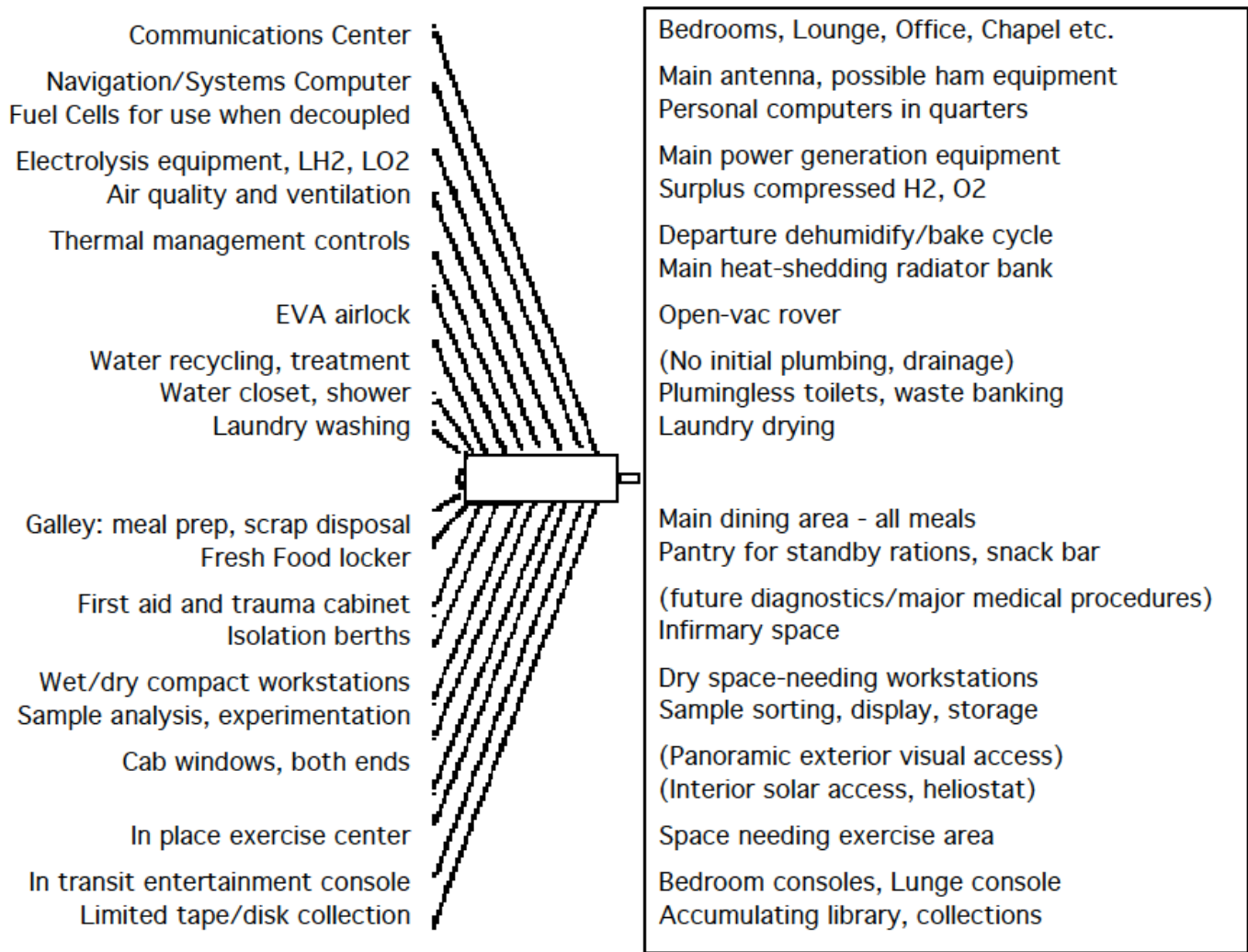
(11) Exterior Visual & Interior Solar Access: Visual access to the surrounding moonscape would also foster psychological well being. The portholes in the coupled vehicle serving navigation and driving needs are likely to provide only restricted views. Windows or viewscreens are likely at both ends of a frog-type craft. Side-wall portholes may or may not be offered.

If feasible, then, the hostel structure ought to provide visual additional and more possibly more panoRamic visual access as well. A technique already demonstrated on a low-tech basis in one Earth-sheltered home in the Kettle Moraine region of southeastern Wisconsin, in which pairs of angled mirrors bring in stunning picture-window views of the surrounding countryside through zigzag shafts, which duplicated on the Moon would conveniently block cosmic rays. This suggests a design approach for hostel architects desiring to visually integrate the hostel's interior spaces with the surroundings. Pulling off the same trick while preserving pressurization against the hard lunar vacuum will require architectural/engineering ingenuity, but seems doable. Such a feature might be more easily built into Lunar hostels constructed on site of local materials.

This would also seem to be the case for solar access, channeling in pools of soul-warming sunshine via a sun-tracking heliostat using either a zigzag mirrored shaft or a 'solid' fiber optic bundle to preserve shielding integrity. The shutterable sunshine thus brought in can be used to highlight focal points or for general lighting during the dayspan. Both of these features may or may not be harder to provide in hostels partly or wholly pre-fabricated on Earth for transport to the Moon. But 'where there's a will, there's a way.' To the point, both options are relatively low-tech and space-eating features that can be more satisfactorily provided through the hostel's expansive structure than through the nook-crammed hullspace of the paired vehicle.

Left: FROG VEHICLE FUNCTIONS

Right: INITIAL HOSTEL FUNCTIONS



III. EVOLUTION OF THE HOSTEL WITH USE

(1) A First Beachhead: If current more ambitious Moon Base plans have to be abandoned and our first beachhead on the Moon is based instead on this hostel-coupled vehicle concept, and if continuing site reappraisal confirms the decision to establish a permanently occupied full-functioned base on the site, two directions suggest themselves. 1) Provided that the architecture and design of the original hostel have been chosen to be expansion- and retrofit-friendly, with each new visit the hostel could be slowly evolved into the stand-alone full-function base desired. Crews would add floor space via plug-in expansion modules or, preferably, by additions constructed of on-site materials as soon as such a capability comes on-line.

Then would come installation of independent air management apparatus, plumbing and water recycling equipment, sundry work stations, laboratories and shops etc. More adequate medical facilities to treat a wider range of needs would be an early priority. The actual order of improvement would depend on logical dependencies, calculated to prioritize redundancy and safety and to allow an acceptably timely shift to permanent staffing. 2) But if the hostel's chosen architecture and design does not readily allow such expansion and evolution, instead of the hostel being wastefully dis-mantled or simply abandoned, it could be preserved as an annex of a totally new base built adjacent to it, serving to house guest visitors for whom the new base complex may have no spare room. That is, the hostel could become an attached hotel, the Moon's first. We suggest that in the case of a first beachhead, this is the preferred path.

(2) A Farside Astronomy Station: Our recommendation is different for a hostel designed to serve remote infrequently tended installations such as a Farside Advanced Radio Astronomy Facility (FARAF). Such an installation may well follow, rather than pre-cede the establishment of an original permanently

staffed nearside Moon Base, so that the latter could be an advance logistical support node for the far-side operation. Following this scenario, the hostel should be designed from the outset with planned expansion and evolution towards permanent autonomous staffing in mind, and an appropriate architecture chosen accordingly. Indeed, it was to show that there is a happy middle ground between the vehicle-tended farside minimalist installation envisioned by NASA and the permanently staffed major installation the astronomers would like, that we set about to develop the hostel concept in the first place.

The Farside hostel should offer more than basic off-hours shielding against the cosmic elements for technicians changing out equipment, repairing, and updating the facility. An expandable astronomical workshop should be an early extra if not part of the original structure, along with a garage and lunar pick-up or tractor. Such assets would make the visits of the tending staff far more productive, especially if limited to once or twice a year, the low level of activity NASA feels confident the agency can support (in lieu of a near-side base!). For as long as visits remain so infrequent, a stand-alone full-function base would be an exorbitant luxury. In contrast, a simple Big Dumb Volume hostel could justify itself with the first visit. And once such a hostel were in place with the appropriate special extras mentioned, the next crew to visit need bring only new and replacement parts for the astronomical installation, and be able to bring more of them, as they wouldn't have to keep hauling workspace and berth space to and fro with them.

Thus the original up front investment in a FARAF hostel, by allowing visiting vehicles to maximize their capacity to carry equipment for expansion of the installation, would promote more rapid growth and development of this facility within the same subsequent budget.

(3) Remote Prospecting Camps: Hostels serving prospectors may or may not develop into anything more. If the prospecting activity does not reveal enough promise and economic justification for further visits to the site, the hostel could be abandoned (to serve as available solar storm shelter or rest stop for anyone happening by) with little waste of investment.

Meanwhile much more extensive prospecting will have been made possible than from a solitary unshielded vehicle with the same size crew. Hostels at remote research and prospecting sites, like the one proposed as a first beachhead, will need to offer a fair amount of unpressurized but shielded work and storage area, to minimize radiation and micrometeorite exposure during routine porch step 'out-vac' activities. So housed repair and maintenance facilities for surface-ranging equipment would be a logical early addition.

(4) Wayside Hostels: A hostel serving as an 'overnight' rest stop and flare shelter along regular trafficways could be built and shielded in one of the ways suggested below for beachhead or research station hostels. But alternatively, such a hostel might simply consist of one or more linked towable mobile modules (perhaps settlement-rendered retrofits of surplus cargo holds or fuel tanks and other scavenged items) parked under the overarching shield of a previously constructed roadside solar flare shelter.

With the lack of right-of-way and clearance constraints on lunar roadways, such mobile units could be built much larger than their terrestrial forerunners. In either case, the roadside hostel may continue to function as originally set up, or, over time, grow to become the nucleus of an all new settlement, depending on the economic rationale offered by the particular location and the resources of those proposing to exploit any such perceived advantages. In that case, as with the original beachhead hostel, it could either itself be evolved and expanded, or kept as a 'motel' annex for the new settlement. A sheltering open-vacuum ramada for roadside vehicle and equipment repair would be a logical first improvement if not already provided, along with a standard-equipment tool and parts crib for user-performed work. A fuel cell changeout/water re-electrolysis station, a battery recharging facility, stocks of emergency provisions and first aid supplies, and standby emergency communications equipment, could follow.

In other words, the expansion, as warranted by traffic and location, would first proceed along the lines of additional user-tended facilities. Only later would regularly scheduled types of full-service be offered by dedicated staff: the truck-stop restaurant (slowly switching to supplementary onsite food production), the bed and breakfast motel, the on-duty expert mechanic, the souvenir-maker, and the inevitable practitioner of the 'first profession'.

In all cases, docking apparatus should be pre-standardized. If we are indeed going to develop the Moon as an integrated part of a greater Earth-Moon or circum-solar economy, the solitary first beachhead must give way to a multi-site world, and hostels will be at the forefront of that global ex-

pansion and acculturation. Any visiting vehicle, frog, toad, or coach, should be able to couple with any hostel.

Code of honor protocols governing visitor behavior should also be standard, expanding on the suggestion above.

As to architecture, building materials, layout, size, method of deployment or construction -- these could vary widely depending upon available technology, resources, logistics, prognosis for the future of the site, and innovating entrepreneurial competition. <LRS>

MMM #50 - November 1991

LOWERING THE THRESHOLD TO LUNAR OCCUPANCY



HOSTELS: an Alternate Concept for both First Beachheads and Secondary Outposts

Peter Kokh, Douglas Armstrong, Mark R. Kaehny, and Joseph Suszynski - Lunar Reclamation Society

IV. HOSTEL-APPROPRIATE ARCHITECTURES

The operative philosophy in making architectural and design choices for lunar hostels, is getting the most usable square footage per buck. Our intent is not to give an exhaustive treatment of the many possibilities by which prefabricated or built-on-site hostel shelter space can be provided. But we point out appropriate considerations that should affect the final choice in each particular case. We have attempted to illustrate some previously unexplored avenues.

Hostels Pre-built or Prefabricated on Earth

(1) **Hard-Hulled Modules:** Lunar hostels established prior to the startup of settlement industry, would be unlikely to employ lunar materials except as shielding mass. That is, it will be necessary to pre-build them on Earth. But neither ready-to-use payload-bay-sized space station type modules, nor structureless inflatables seem ideal for the purpose. The former quite simply offer inadequate space and if brought up to the Moon empty, will squander payload bay capacity. Multiple modules stuffed with provisions and serving as temporary cargo holds, to be unloaded on the Moon and then interconnected, are a more reasonable possibility. But their deployment would call for an unwelcome load of high-risk crew EVA hours. It seems the wiser course to reserve human activities on the Moon for tasks that can be performed under shelter. The modular approach does, however, allow the hostel complex to grow with each new visit.

(2) **"Telescoping" hard-hull designs** are another story. Prebuilt hostels of this type could be built to extend, unidirectionally or bidirectionally, with the smallest diameter section (1) being loaded with built-in features and the wider diameter telescoping sections offering simple unstructured spare volume. The inside walls of these sleeves could be furnished with electrical service runs, flush lighting, recessed attachment points, etc. Deployment would be accomplished via simple pressurization which would securely force together properly designed o-ring-fitted inner and outer flanges providing a seal with more than sufficient mechanical strength to maintain integrity under any likely interior traffic/use.

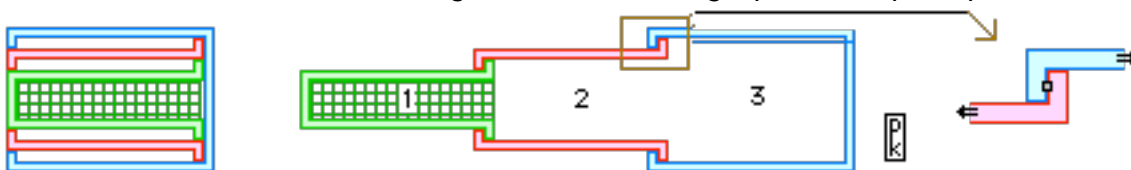


Figure 3A: Telescopic Module: The thickness of the sleeve walls, and the amount by which one is smaller than the other, is exaggerated to show detail.

Alignment would be preserved by the simple expedient of a key/keyway feature with keys on the outer flanges and keyways on the outer surface of the inner sleeves. Outrigger skid-dollies attached to

the smaller ends and the outer flanges of the widest diameter middle sleeve, riding freely on a pre-levelled compacted gradeway, would midwife the deployment. Airlocks or docking ports could be placed at either end, but only the widest sleeve could have a side-mounted protrusion. A pair of bidirectionally expanding units could turn this to advantage to conjoin "H" style.

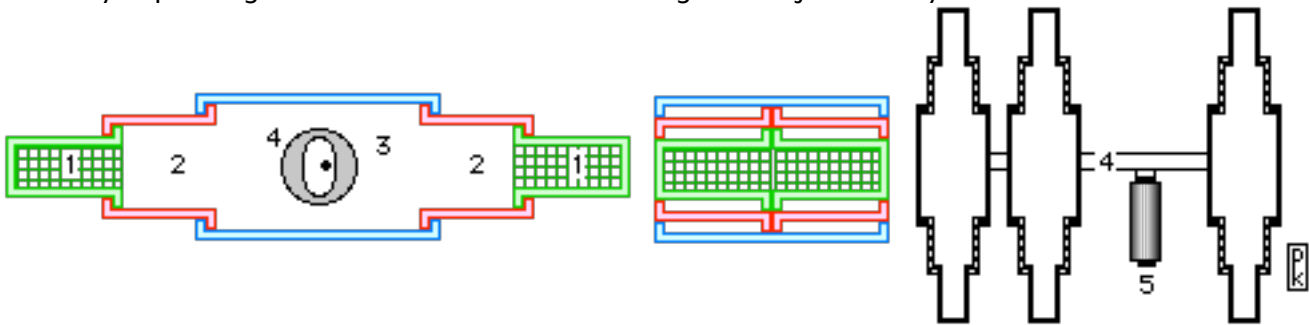


Figure 3B: Bi-telescopic Module: [4] connector tube. [5] docked frog, perhaps under a shielded canopy..

In fact, any number of such units could polymerize in like fashion. For this reason, we have dubbed the basic unit the "monomer". The beauty of this bi-telescopic design is that it allows a single payload bay to deliver perhaps two and a half times its own usable interior volume. The apparent drawback of the strongly linear floor plan (and required special attention to site preparation) becomes a potential plus through H-H hookup possibilities. We think this telescopic approach to hard-hull modularity is much more promising than any of the more conventional segmented approaches. Indeed, such a configuration might also prove to be the eventual architecture of choice for full-function lunar bases and non-gravid orbital stations as well. Single units would be especially trailerable and might thus be ideal for manufacturing in the lunar settlement for trucking to roadside locations about the Moon, to be deployed under previously built emergency flare sheds.

3) Simple Inflatables come in spheres and cylinders, shapes with unstable footprints and awkward to work with if not pre-decked. In free space, the inflatable cylinder can be subdivided in radial cross sections, its caps serving as top and bottom. But on the Moon, one can only lay such a shape on its side, especially given the need for shielding. Then, as with the inflatable sphere, the inconveniently curved inside bottom surface has to be somehow decked over. Nor do pure inflatables lend themselves easily to even modest built in features and furnishings. An alternative we do not recall seeing treated, is the inflatable torus which would seem to offer maximum stable footprint per usable volume.

(4) **"Hybrid" Inflatables** were examined next. These are structures employing both hard, feature-loaded elements and soft inflatable sections.

a) **First we sketched a flat footprint "sandwich" model**

The "sandwich" has a prefab floor section with pop-up built-ins and utilities, paired with a prefab ceiling section with built-in lighting and pull-down features, the two slab units connected by a peripheral inflatable wall. (The curvature of the walls, providing maximum volume for combined flexible and rigid surface areas, would follow the lines of a projected cylinder of the same diameter.) Collapsed for transport to the Moon, such a hybrid could offer clear flat floor space a full fifteen feet wide if designed to fit the Space Shuttle payload bay or up to 27 feet wide if designed to fit an inline (top-mounted) shuttle derived cargo faring. Such hybrids could be deployed with significantly less crew EVA hours, or even be tele-deployed. To the improvement in habitable volume as compared to the rigid module traveling in the same hold, the folded "sandwich" would make room for plenty of additional cargo, both by taking up less space and by weighing less.

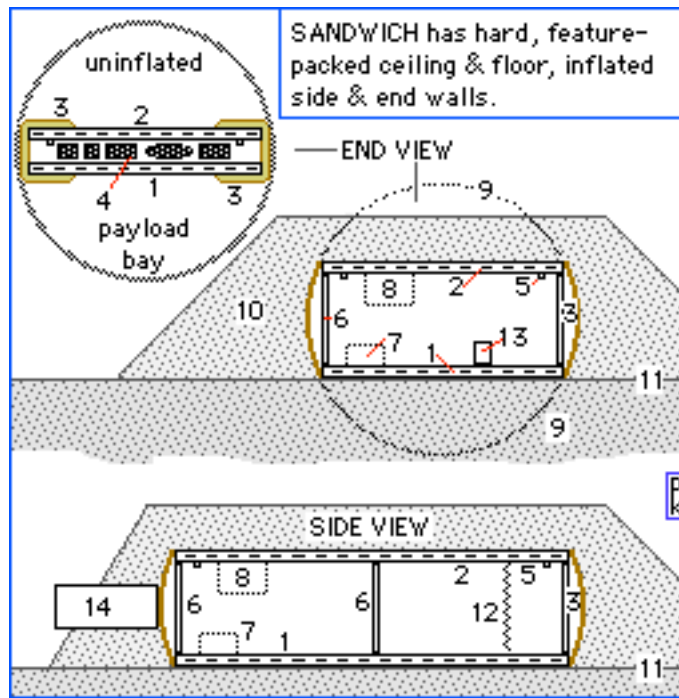


Figure 4: The Sandwich:

- | | |
|---|--|
| [1] Floor module with pop-up built-ins. | [2] Ceiling module with pull-down units. |
| [3] Inflatable sidewalls and end walls. | [4] Collapsed loose furnishings |
| [5] Cove-lighting tubes or bulbs | [6] Contingency support poles & utility chases |
| [7] Representative floor pop-up feature | [8] Representative ceiling pull-down feature |
| [9] (Curvature of inflation extended) | [10] Soil overburden for shielding |
| [11] Original graded & compacted ground contour | [12] Pull-down pleated room divider |
| [13] Representative loose furniture item | [14] Docking tunnel |

While the great advantage of the sandwich design is that it offers a stable flat footprint and a ready to use flat floor, it offers little more than half again as much space as a rigid module designed to travel in the same cargo hold.

Another configuration, which we've dubbed the "slinky", features rigid feature-packed cylindrical end caps connected by a cylindrical inflatable mid-section. Here instead of multiple circular ribs and worm-like segmented lobes, we strongly suggest using a continuous helical rib spiral, as this helical design choice offers an elegant opportunity to build-in a continuous electrical service run along with other utility lines and lighting strips within this skeletal "monorib."

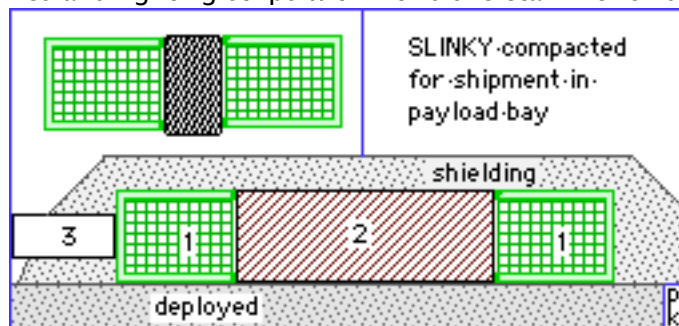


Figure 5: The Slinky: [1] Pair of rigid end caps, outfitted with built-in features and equipment. [2] expandable slinky module (unfurnished). [3] docking tunnel.

b) **Next we came up with a novel wide-floored lunar "quonset" idea.**

The "Quonset" has a stable footprint and favorable width to height ratio. While all the built-in features would have to be floor-housed pull-ups, this design offers about two and a half times as much floor space as the "sandwich" for the same payload bay space. The inflation-reinforcement of a triple

slab hinged floor is a design innovation that offers opportunities for crawl-space storage, utility space, and ventilation worth pursuing. A telescoping vestibular passage-way for vehicle coupling could be built into one or both inflatable end-walls as illustrated.

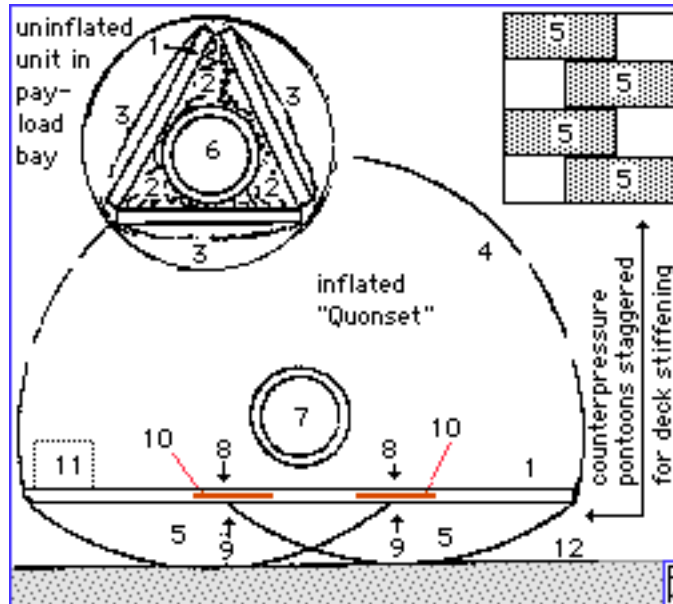


Figure 6. QUONSET: [1]Hinged 3-section floor deck. [2] uninflated quonset roof/wall
 wall
 [3] uninflated floor support pontoons [4] inflated quonset roof/wall
 [5] Inflated floor support pontoons [6] In transit position of docking module
 hinges [7] Docking tunnel in end wall [8] Downward air pressure on
 [9] Counterbalance pressure on hinges [10]Contingency stiffening bars
 [11] Representative pull-up feature [12]Ground contour before shielding

d) Finally, we sketched a hybrid torus design, dubbed the “donut”

In this design, the “donut-hole wall” is replaced with a compact payload-bay sized hexagonal “works” module loaded with pull-out built-in features including top mounted central solar, visual, and EVA access, side-wall vehicle docking port, decking erected from parts brought up in the core module’s “basement”, complete with a peripheral jogging track.

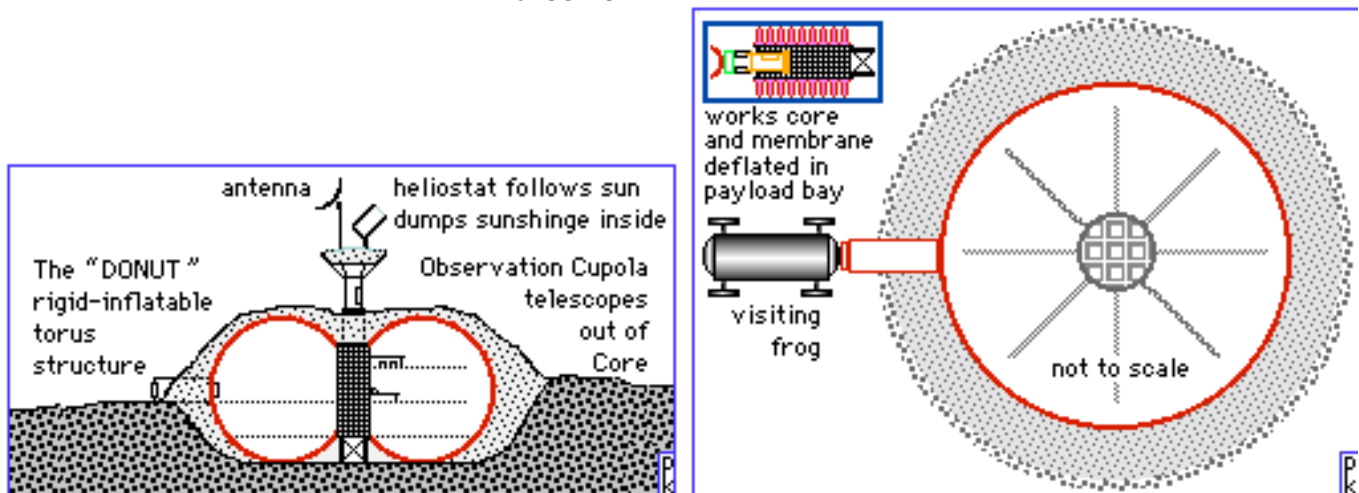


Figure 7: The Donut: This 3 floor model at top is an upgrade of the simpler design in the original paper. Shown is the central works-packed core, optional telescoping observation & EVA tower, antenna, heliostat. Docking tube is at left. In this version, a small crater was chosen to make shielding emplacement easier and to allow the frog access to the middle level. Center left: a crude sketch of

how the package arrives deflated in a payload bay, and a view of the donut hostel and docked frog from above.

Taking further advantage of this design, the naked inner surface of the outer side wall could easily be pre-painted or pre-printed with a 360° panoramic mural medley of Earthscapes, Spacescapes, and Moonscapes. The sketch above suggests a peripheral walkway to take advantage of such an opportunity. By including two additional coupling ports in the donut's outer wall at 120° angles we would make possible 'benzene ring' clusters of individual donut units for indefinite "organic molecular" expansion potential.

Small conventional instrument-packed modules could be brought up from Earth and coupled at unused ports to allow endless upgrade of the facilities. Of the hybrid inflatable designs investigated, the "donut" seems to lend itself best to all our various design goals. We intend to work with this central core torus design further to bring out its full promise and tackle any unsuspected problems.

e) The "Trilobite"

Once the paper was in the mail to make the publication deadline for the conference proceedings, we thought of yet another promising configuration. In the "trilobite", the core works cylinder lays on its side suspended between two larger inflatable cylinders. The area below the core cylinder forms a sheltered bay or ramada for vehicles and routine EVA.

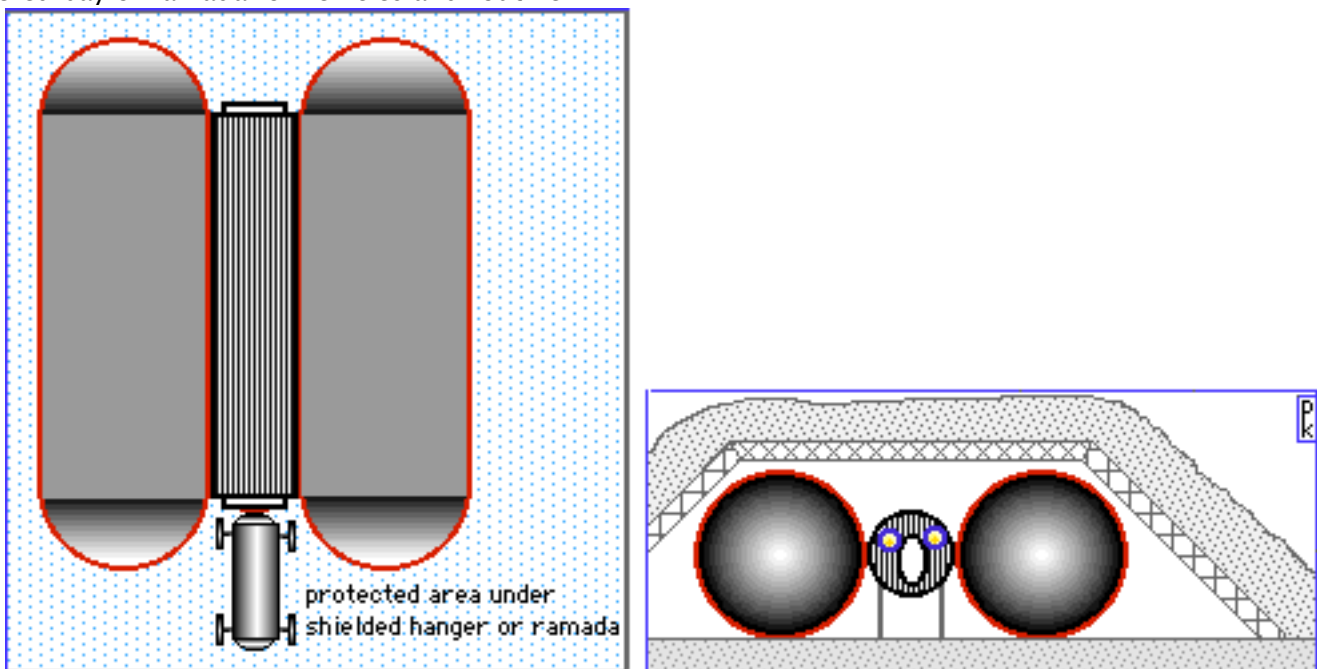


Figure 8: The Trilobite: The works core module could be scaled to a 15' wide shuttle payload bay or to a 27' wide faring atop an External Tank, with inflatable cylinders proportionately sized. Here, the trilobite hostel sits under a shielded hanger, making servicing and expansion much easier.

If hybrids are designed as connectable modules for expansion, the vehicle docking port design chosen for standardization should also serve as a module to module connect. This will offer the greatest versatility. Where rigid ribbing cannot be included (all the above designs except the "slinky") hollow ribbing with a post-inflation fill of rigidizing foam could provide structural support if pressurization was lost. However such a foam must be carefully formulated to drastically minimize noxious outgassing as we are dealing with sealed structures that can't be 'aired out'. The hybrid, while still more limited in size than the pure inflatable (though it comes close in the torus format), offers measurably greater usable floor space than a hard-hulled module designed for transport in the same hold, yet can be full of convenient built-in features. The hybrid, in comparison to the retro-furnished simple inflatable, offers comparable savings over rigid shelter in total imported mass. Thus the hybrid inflatable seems to be the best of both worlds. We have only begun to scratch the surface of this promising world of hybrid inflatable design, and present our first fruits for your stimulation and input.

(5) Shielding for Prefabricated Hostels:

Since full tele-deployment would be ideally appropriate for these intermittently staffed outposts, ways of covering the hostel with regolith shielding by robotic or teleoperated means should be re-

searched. The needed equipment could be small and lightweight with minimal power, as, working slowly prior to the arrival of a crew needing protection, there need be no hurry to finish the job. Perhaps this task could be performed in such a way that the shielding regolith might be gathered as part of the process of grading and compacting a launch pad and a driveway or taxiway to the hostel for visiting frogs to follow. The basic idea is that the first humans to return to the Moon since the departure of Apollo 17 find a cozy place waiting.

Hostels Built on the Moon of Native Materials

The ultimate potential for ample 'Big Dumb Volume' will not be realized until we begun self-manufacturing building materials, modules, and components from native materials, either in-situ, or at a factory site for overland or suborbital delivery to remote sites. Glass glass composites ("glax") or lunar steel are likely to be the building materials soonest available in an upstart settlement. "Lunacrete" would be a competitor if economically recoverable amounts of water-ice are found in lunar polar "per-mashade" areas. Glass-fiber reinforced cast basalt is an option that seems especially suited for opening remote sites, with modules being manufactured on site by mobile facilities. [2012 Note: Basalt fiber industry is far advanced and appears to have superior qualities.]

CONCLUSION

The hostel concept rests squarely on acceptance of calculated compromises. Such choices run counter-flow to the spread of risk-free expectations in the public culture, something to which any public-funded space program is especially vulnerable. Yet this paradigm promises to both significantly lower the threshold for human return to the Moon, and to significantly accelerate the breakout from any form of first beachhead towards establishment of a truly global presence there. We believe there is more than a bit-role for such "hostels in a hostile land." Meanwhile, many of the ideas explored in the course of developing our topic, would appear to stand on their own. << LRS >>

MMM #52 - February 1992



The Role of the Campfire



Many things have worked to humanize and civilize our ascending species over the ages. Surely one of the earliest, and one which to this day continues to act as a social catalyst, is the campfire, the fireside, the hearth. Around the fire stories are told, songs sung, and myths and legends passed on. Many a science fiction yarn has its characters plotting by the warmth of a fire on some star-sunned planet - one with breathable air, of course. But elsewhere in our own Solar System, fire's mystic magic may be denied us, unless (see FIRESIDE, below)

On the Space Frontier, can there be any

FIRESIDE

around which to gather?

FIRESIDE By Peter Kokh

Since time immemorial, ever since the taming of fire, humans have sought warmth, comfort, and company huddled around campfires and hearths. Even today, when a dwindling number of modern homes boast the luxury of a fireplace, nestling around the fire is something we all enjoy - when it is

cold or damp, when we are out camping, on a clambake or a picnic in the park, or just out on the patio or in the back yard for a barbecue or marshmallow roast. And can any of us forget the bonfires after a high school homecoming football games?

While nowadays, such pleasures are scarcely everyday experiences, however infrequently enjoyed, the magic of the fire is so much a universally positive experience that it is still possible to ask: "can it be humanity if there is no campfire?"

In "FIRE DEPT." MMM # 51 DEC '91, we pointed out the very intolerability of open fire, controlled or not, in the very limited atmospherules of mini biospheres. But that is not the last gloomy word, for it only applies to fires in which the combustion products are smoke and toxic gasses.

In MMM # 40 NOV '90 "METHANE" we discussed the possibility of controlled burning of compost-pile derived methane to produce water vapor along with CO₂ for plant nourishment. Such combustion will need to be confined to nitrogen-free chambers so as to avoid unwanted nitrogen oxide byproducts. Could such a methane-oxygen fed flame in a glass-faced chamber serve as a fireplace substitute? Why not?

It should also be possible to devise a tightly confined hearth "substitute" that slowly fed together pure hydrogen and oxygen. If again the burning is confined to a nitrogen-free chamber, the only combustion product would be steam - pure water, which can then be used for drinking or other purposes. In effect, we are talking about a modified fuel cell, in which the $2H_2 + O_2 = 2H_2O$ reaction is run somewhat faster, not so fast as to be explosive, but fast enough to sustain a flame, perhaps with a harmless enough additive (if one can be found!) to colorize the normally invisible H+O fire.

I'd be surprised if either such device now exists, with little market for them - down here. But out on the frontier, a flame-in-a-jar device might create enough symbolic warmth and cheer to become commonplace in settler homes on the Moon or Mars or elsewhere, in gathering spot lounges, even on long trips aboard spacecraft or surface roving coaches.

Why not tinker up such devices now? The methane version could not be used in draft-tight close quarters but a hydrogen hearth might sell to apartment dwellers, especially singles wanting the latest in trendy mood-setting gizmos. Just knowing that we could take such "fire chamber" with us, could make the prospects of life on the space frontier just a little less daunting, just a little more reassuring.

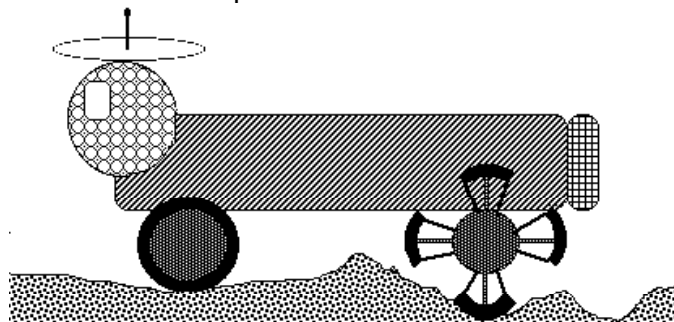
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MMM #54 - April 1992

INVENTORS WANTED

Serious would-be explorers of The Moon have been busy developing a variety of wheeled and walking vehicles and robots to cover the boulder-strewn expanses of this barren world.

The trouble with wheels, is that they are too easily defeated by a host of obstacles. The Moon has no roads. Yet walkers can negotiate easy terrain at only a snails pace. So why not combine the virtues of both? Tinker a walking vehicle that can let down a set of wheels when the way gets easy, or a wheeler that can switch to legs, or whose tires can sprout feet?



MMM #55 - May 1992



Beyond “Mole Hole City”

Our expectation of what a Lunar Outpost or Settlement might look like from the vantage point of a surface overlook has become one of a monotonously drab pattern of regolith mounds, the telltale sign of pressurized living space below. This “molehill-scape” is little relieved by its punctuation with occasional observation cupolas, exposed air locks, solar arrays and heliostats, peripheral tanks of volatiles, and other external warehousing. “Once you’ve seen one moonburg you will have seen them all.” Not necessarily so! Eventually Lunan architects will rise to the challenge. See below.



SKYSCRAPERS By Peter Kokh

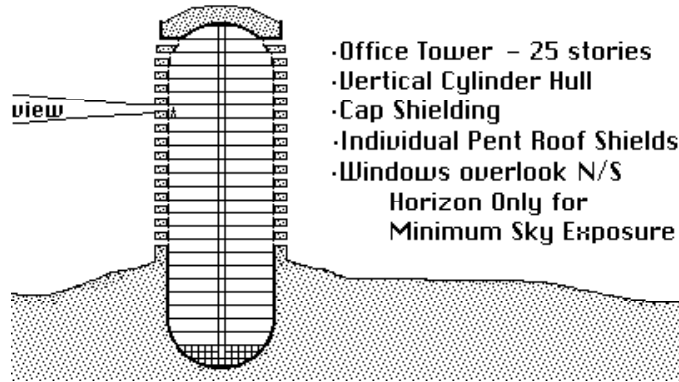
Perhaps you’ve seen artistic visions of future Lunar and Martian cities replete with modern skyscrapers and flying roadways, all under protective domes of glass or some superior glass-substitute. We touched on this distant possibility in both of the last two issues. Certainly there is much more room for creative license on the part of architects working within the protected “middoor” volumes of megastructures like domes, and shielding vaults such as that illustrated in the Prinztown design study [see MMM #s 26-31, esp. # 29 p.4].

But looking at possibilities in the nearer term, when pressurized structures will be individually shielded, we might ask if Lunar and Martian xitiscapes can escape the mole mold of mound rows of shielding soil, hiding cramped lifespaces below. The appearance of this shielding overburden is our topic in the piece that follows: MOON ROOFS. Here let’s explore how architectural ingenuity can help a thriving Lunar or Martian settlement break out of the terrain-hugging rut.

Traditional skyscrapers here on Earth, as varied as they be in style, are basically vertically elongated boxes. Such a shape will not work well if it has to contain atmosphere under pressure against a surrounding vacuum. While higher surface strength to volume ratios allow more freedom with very small structures, on the greater scale of the multi-story building exo-architects will have little option but to somehow adapt the sphere, cylinder, or torus, all of which do a much better job of equalizing pressurization differential stress. There is, to illustrate, no reason that a cylinder couldn’t be employed in the upended position, properly anchored, with its internal floors perpendicular to its long axis, instead of parallel to it.

So much for meeting the pressurization challenge. We must still find a way to preserve shielding integrity. A simple outer sleeve a couple of meters (6 ft. or more) out from the cylinder’s pressure hull, creating a wraparound coffer dam for filling with soil, would do the trick. But that certainly does not present the architect with a satisfying form of statement. The whole idea of multi-storied buildings is not merely to create an imposing silhouette against the sky, nor to make efficient use of high cost real estate, but also to allow visual access to the ambient outdoors sun/daylight and to the views generous window-walling can provide.

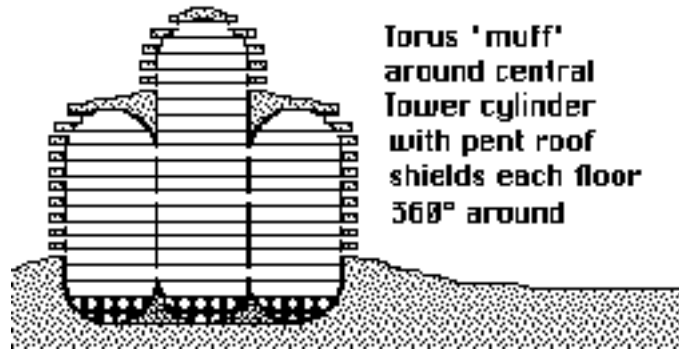
If you accept that such structures on the Moon and Mars would be occupied only part time by office-workers, for example, and if you restrict the field of unshielded vision to “a couple of horizon-hugging degrees” or so, vertically tunnel-visioning the view of anyone wanting to look out, the total averaged exposure to cosmic radiation from unshielded sky could be kept to an acceptable minimum, even on a long-term basis. If the simple illustration below reminds you a bit of the oriental pagoda with its tiered “pentroofs”, that is no accident, for that is the source of the inspiration.



- Office Tower – 25 stories
- Vertical Cylinder Hull
- Cap Shielding
- Individual Pent Roof Shields
- Windows overlook N/S
Horizon Only for
Minimum Sky Exposure

What appears to be balconies in this sketch, are really continuous cantilevered coffer dams filled with loose regolith soil shielding. Building occupants are restricted to the interior of the fixed pressure-holding windows to the inside of these “pent roofs”.

This gives us an architectural “language” that can be used in yet more expressive forms. Below we have a vertically stretched torus “muff” surrounding a central cylindrical tower.

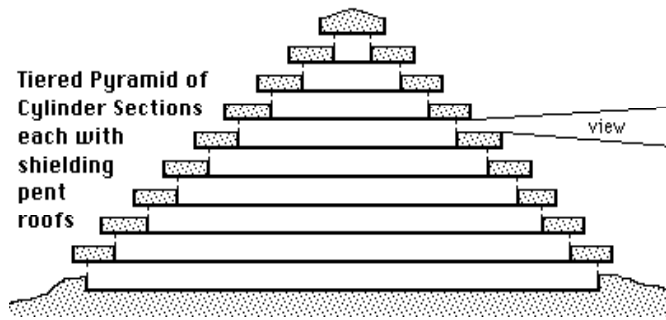


- Torus 'muff'**
- around central**
- Tower cylinder**
- with pent roof**
- shields each floor**
- 360° around**

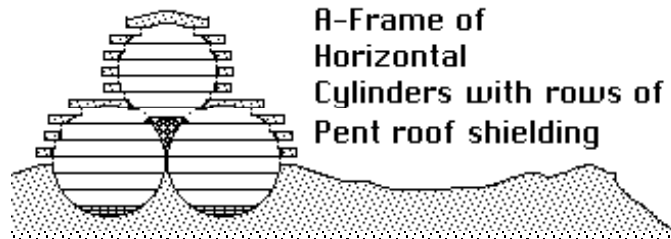
The inner and outer walls of the stretched torus would have to be constrained to shape by floor-incorporated cables under tension.

Another possibility may be to stack (co-axially, or perhaps stylishly off-center) story-thick sections of cylinders of decreasing diameter, each with an attached pent roof soil bin to shield observers inside from the greater portion of the naked light-black, radiation-bright sky above.

The wider the diameter of each story section in proportion to its height, the greater the need to keep floor and ceiling in parallel, not by support pillars under compression, but by vertical (faux column hidden) restraint cables under tension. For unfortunately, the weight of the soil overburden sufficient to provide the needed amount of radiation shielding, is no match in the light lunar gravity (“sixthweight”) for the expansive pressure of the “atmospherule” below against the vacuum outside. On Mars where the gravity is two and a quarter times greater, the same amount of shielding soil mass will exert that much more of a stress-relieving counterpressure on the building “hull”.



A less pretentious example of sky-scraping is given in the end-view cross-section sketch below, where a number of horizontally placed cylindrical pressure hulls are stacked. The advantage is in longer rectangular floor space.



By whatever structural idiom it is stated, just as in some terrestrial cities, the skyscraper can be given even greater visual impact by siting it on high ground relative to the general surroundings (like the famed Shangri-la inspiring 2500-roomed Potala palace in the center of Lhasa, Tibet) e.g. on a crater wall or central peak, a scarp or lava flow front, etc.

And, of course, purely decorative unpressurized doodads such as spires and minarets or other façade-making hull-disguising decor can be added for tasteless kitsch allusion to one or more of the many Earth-legitimate building styles of past and present. We can only trust that most future Lunan and Martian architects will see the value of learning to express themselves in authentic world-appropriate forms. But it is a free universe!

Perhaps you can think of further distinctive directions in which future settlement architects can give vent to their vertical aspirations. If so, we hope you will send them in to MMM so we can share them with our readers.

But, is there a need? Will lunar settlements ever grow big enough for the real estate at their cores to become valuable enough to justify the extra expense of high rise construction? Certainly not if they are or remain government artifacts. But if settlement is enterprise driven, first supplying raw materials, then value added products, exploiting every advantage, and diversifying its own domestic economy, there is no reason why the number of pioneers on the Moon cannot rise into the hundreds of thousands or more within a half century of their founding. Remember, for a largely self-sufficient economy, the export sales needed to cover import costs will be relatively small. In the context of a rapidly diversifying economy, in comparison to the rise in exports, the growth of the supported population can be exponential (e.g. a 10-fold rise in exports for a 100-fold rise in population).

The rise of settlement “downtowns” and of metropolitan and regional market centers should be expected if we are to have a real expansion of the human economy through off-planet resources, i.e. a spacefaring civilization. In this setting, the appearance of skyscrapers within or without enveloping xity megastructures should not be surprising.

But settlement skyscrapers should also not be seen as a foregone conclusion. While they might be considered for hotels, offices and corporate headquarters, residential condominiums, government buildings and so on, for each of these needs there are plenty of ground-hugging horizontal models. Indeed, if there has been adequate xity planning, the need for Manhattan style density should never arise. What multi-story buildings are built may be very modest by Earth standards.


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Rather than “scrape the sky”, lunar multi-story buildings will “break the horizon”.

=====

Indeed there will likely be operative on the Moon a strong DISincentive to dense high-rise building: the neighbor's right to unshaded access to the Sun's valuable rays. This may mean that multi-story buildings must have proportionally great east and west setbacks, so that they do not rise above a certain rather low angle above the horizon, say 10° , at the property line. In such a situation, the vertical high rise is no longer an efficient use of real estate. (In theory, the best solution would be a very, very shallow broad-terraced pyramid.) The view (for residents or occupants) and the image (for customers and clients) then, may well turn out to be much more important drivers than the efficient use of "foot-print".

Terrestrial suburban office parks that have become common in the past decade, offer a more realistic inspiration for lunar high rise developers. Rather than "scrape the sky", their constructs will break the horizon. Nonetheless, they will shatter forever the image of lunar towns as "mole hill city".

Visitors to a lunar metropolis will ride "middoor" coaches plying the xity's pressurized avenues within the shared biosphere. But they will also peer out over the surface xity-scape from shielded overlooks within the various high rises, and get a good outside perspective from the pressurized out-vac coach to and from the spaceport. Finally, in $1/6 G$, a space needle observation tower could easily be a mile high! 



MOON ROOFS By Peter Kokh

Roofs on the Moon? – where it never rains or snows? Ah, but it does rain – a gentle slow micro-meteorite mist, and a steady shower of cosmic rays, plus sudden 'cats and dogs' outbursts during solar flare episodes. While the characteristically imbricated (tile or shingle overlap) shedding features of terrestrial roofs would not be called for, the sheltering function of the 2-4 meters (6+ -13 feet) of shielding overburden above Lunar or Martian habitat space will be more than a little analogous to the familiar roof, a prehistoric heritage.

To the architect, the roof has traditionally been one of the most important opportunities for statement of style. To give some outstanding examples: the thatched English cottage, the terra cotta Spanish Tile roofs of the University of Colorado in Boulder, the green-patina copper roofs of many early urban skyscrapers, the onion domes of St. Basil's in Moscow's Red Square, the tailored French mansard, and the Pagoda.

It would be natural for future settlement architects in the employ of well-to-do façade conscious homeowners to turn to the shielding blanket as a clay for expression. And for those hired by companies seeking a striking design for their new headquarters building, to turn to lunar "roofs", alias shielding, as a medium of style.

Already, purely for the utilitarian reason of simple convenience, some outpost designers are specifying that their habitats be neatly sand-bagged. The advantage of placing the loose lunar regolith in bags should be obvious. Not only will it keep the construction site cleaner – and safer (from dangerous bulldozer module collisions) – it will allow the bag-tamed shielding to be easily removed in order to repair hull and joint leaks, to make structural modifications, and to exchange old, or attach new, expansion modules. Meanwhile, by this simple trick of bagging, the external appearance of the outpost is drastically altered. The 'lith-bagged outpost now looks like an on-surface installation rather than an under-surface one, its appearance and presence radically transformed.

An alternative to the bag or sack (which could be made on site from medium-performance lunar fiberglass fabric) would be sinter blocks made from compacted and lightly microwave-fused soil. By varying the size and shape of such blocks and the patterns in which they are stacked, distinctive igloo-like styles should be easily achieved.

Grecian Formula

It does not stop here. There is no cosmic law that states lunar shielding must be gray, or Martian shielding rust-hued. If desired, colorants can be added to the material itself, or glazed or even merely dusted on an exposed, rough surface.

In the early settlement, the availability of colorizers will not be great. On the Moon, Calcium Oxide, CaO, i.e. lime, made from highland soil will be a likely early favorite, probably cheaper than mare ilmenite-derived Titanium Dioxide, TiO₂, also white. Either way, “white-washing” Lunar settlement shielding mounds might early on become “politically correct”, for they would make the settlement a conspicuous very bright spot on the Moon’s surface, perhaps even outshining the crater Aristarchus. This would make Earthlubbers more conscious, and hopefully supportive, of their frontier-blazing brethren above – a cheap way to put any Moon town in the “limelight”!

More than empty vanity

By the simple addition of shaping or sculpting or colorizing, the shielding mound will become more than a visual disturbance of the surface. The ‘lithscaper’s or architect’s touch can imbue the protective mound with design, unearthing the presence of the living and work space below and making the otherwise hidden structure visually present above the land-scape in an identifiable, pride-investing way.

This transformed self-image of the settlement may have real positive effects on the outlook, mood, and morale of the pioneers themselves. For it can be an early, easily won battle in a campaign to “humanize” the sterile barren alienness of their surroundings, thus contributing subtly to a sense of being “at home” in their adopted raw new world.

Economic opportunities

Indeed, outside of the occasional observation cupola, for most surface settlement habitat architects, the “roof” may be the principal opportunity for exterior public-side statement (other than any openings to also shielded public “middoor” spaces like pressurized roadways, passageways or squares etc.) But the opportunities for “roof”-styling will more than reward frontier architects. This market will also provide entrepreneurial openings for enterprising settlers to develop the additives, the tools, the equipment, the processes, for making such on-paper possibilities real off-the-shelf choices.

Bower Roofing

Nor need ‘roof adornment’ be an expensive luxury item. For it could also serve as an at least temporary ‘banking’ outlet for otherwise hard to recycle used building materials and other non-organic ‘debris’ – perhaps in shredded or gravelized form – and for various orphaned manufacturing and mining byproducts for which more suitable uses are not yet in sight. These are two stubborn categories which contribute significantly to terrestrial landfills, yet receive little if any attention. Here we could take a page from the bowerbirds (8 species in Australia, 8 in New Guinea) who decorate the interiors and entrances of their nests with “found” objects of all sorts.

Settlement Signatures

Without attention to shielding style, it could well become a prevailing truism that once you’ve seen one surface frontier town, you will’ve seen them all. Given human nature and the slightest modicum of discretionary private and public funds, it is unlikely that such will be the case.

Distinctive ‘lithscaping and “roofing” styles may become characteristic identifying trademarks, not only of individual structures, but of different lunar and Martian towns taken as a whole. And there will be economic incentive, and payback, for the small expense involved in the form of tourist interest in “local flavor”. Long before any Lunar or Martian towns become large enough to begin to grow small high-rise “downtowns”, they may become identified in the tourist mind by their individual mix of “roofing” styles. And all it will really take is a wee bit of imagination!

MMM

MMM #58 – September 1992

An Alternative Moon Buggy

**Internal Combustion Engines for Lunar Surface Transport
with powdered metal serving as fuel.**

By Michael Thomas, Seattle L5 Society

Eccentric automobile designers have through the years built cars that run on a wide variety of fuels, from alcohol to manure. One designer has built a car that is fueled by left-over grease from the deep frying vats of fast food restaurants. But the design that most startled me when I learned of it, is an automobile engine that is fueled by powdered coal. I never before imagined that an internal combustion engine could burn a solid fuel.

I do not advocate coal-cars, as they would be polluting, but solid fuel opens a whole new world of possibilities. It is not so surprising really if you think about it. How many times have you heard of a grain silo exploding because wheat dust reached explosive concentration and was ignited by something. And while "flour power" may not be the answer to dependence on oil, there are many powders that will burn.

The Moon is very rich in certain elements, most abundant of which are oxygen and silicon. Silicon combines with oxygen (burns) to form silicon dioxide, glass. Many lunar materials are silicates, and silicon could with effort be separated out and processed into a fine powder. Once powdered it could be injected into an engine's combustion chamber along with some liquid oxygen, then ignited with a spark.

Other elements abundant enough on the Moon to consider are aluminum, magnesium, titanium, and potassium, in that order. Separating aluminum from ore requires vast amounts of electricity, so it may not be the best choice, even though it burns well.

On Earth, titanium is far too rare and expensive to use as a fuel, but on the Moon, in some areas, it is more abundant. It also requires somewhat less energy to separate from ores than does aluminum. Export potential might make titanium valuable on the Moon, something one would not waste, because it can be sold for money or traded for other elements, like carbon and nitrogen, which are scarce on the Moon. But burning titanium as a fuel on the Moon would not really waste it.

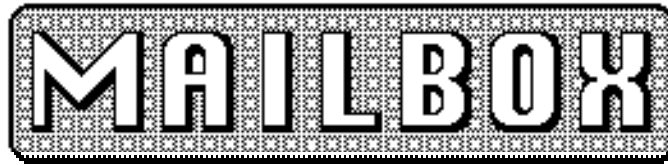
Because the Moon has no atmosphere, burning fuel there could not cause air pollution: there is simply no air to pollute. So where would the exhaust ash from such an engine go? It would simply fall to the ground, where it would remain indefinitely. And while this titanium dioxide (or other metal oxide -- there is a significant amount of unoxidized iron fine particles in the regolith) dust on the road surface and vicinity reaches some predetermined concentration or depth, it could easily be recovered by a surface skimmer of the sort used in regolith mining and processing. The metal and oxygen could then be separated and once again burned as fuel. Because of the ease of recovery, this would be a renewable, reusable fuel. Very little would be lost or wasted in the long term. Fuel use would increase only with increases in population and economic activity. Because of the renewability of powdered metals as fuels on the Moon, mining operations would not have to support a constant demand for fuel. Only a small fraction of their powder would be diverted for use as fuel. Most of it would remain for use in domestic industries and for export to Earth or elsewhere.

Another potential fuel, potassium, has the unique property of self-igniting on contact with water. But it is also easy to ignite in the presence of pure oxygen. Since metals burn at high temperatures, igniting a metal dust fuel may not be as easy as igniting a flammable liquid. Of the metals available on the Moon, potassium will ignite most easily and at the lowest temperature, which may make it ideal for a metal dust engine. Magnesium also burns well, once ignited, and its abundance in lunar highland rocks is around eight percent.

One drawback to a metal dust engine is that metal dust burns at very high temperatures compared with more traditional (liquid or gas) fuels. And in the Moon's airless environment, cooling such an engine would be difficult. Some of the engine's heat could be used to heat and vaporize the oxygen just before it is injected into the chamber. And if the vehicle were to carry more LOX than it needed to oxidize all of its fuel, some could be routed through the engine block, where it would be heated and vaporized, then released, carrying the heat into the lunar vacuum. Even so, the engine would likely run very hot. Possible solutions to this problem include the use of a titanium engine, possibly with ceramic coatings.

Unlike electric vehicles, they would not be dependent on solar energy for refueling that is available only 50% of the time. (While electric vehicles could operate during the long nightspan, they would likely limit their activity to the use of a single charge of their batteries, due to power limitations when the solar grid is down.)

Metal dust engines have other possible uses, such as driving generators for emergency or supplemental power during the nightspan when solar energy is not available. They could also be used to drive heavy equipment and industrial machinery where large amounts of electric energy are not yet available. <MT>



On Windows in Lunar Xity Skyscrapers.

I have a question for you. How can you have windows in Moon structures with all the debris zipping through space? I see that your illustration [SKYSCRAPERS on the Moon, MMM # 55 pp 5-6 MAY '92] that the openings are to horizon views only, but even so there are tangential paths that could be tough on windows. And direct sunlight also would be something to be avoided, probably by choosing the latitude of the site.

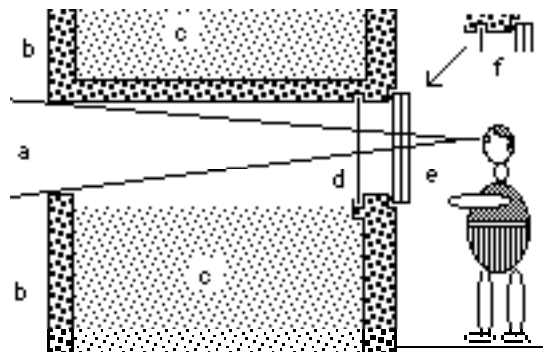
Dick Linkletter
Bremerton, WA

EDITOR'S REPLY: Assuming a non-polar site, only horizon-hugging windows to the East and West would get direct sunshine. This can be handled either by not having windows in these very directions or by suitable automatic shuttering at the appropriate times (sunrise and sunset dates).

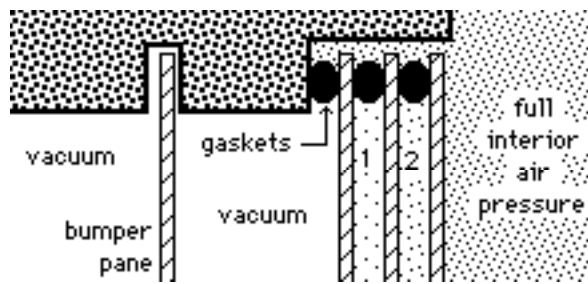
As you can see from the illustration in the SKYSCRAPER article, the windows are set well back several feet in horse-blinder openings through the shielding so that the field of view is quite restricted. This not only would allow openings to the ESE, ENE, WSW, and WNW but also restricts exposure to incoming surface tangential meteorites to just that portion coming nearly head on.

Nonetheless a significant if diminished danger does exist and this vulnerability must be addressed. I would suggest that in addition to multi-paning with graduated pressurization between the panes to handle the full inside pressure to vacuum differential, that a free-standing removable and replaceable ("sacrificial") fore-pane of shatter-resistant optical quality glass-glass composite be used. This bumper-pane, physically separate from the sealed window unit proper, would absorb almost all micrometeorites and could be replaced when pitting begins to interfere with vision.

Space debris is confined, fortunately, to low Earth orbit. Anything near the Moon is quickly purged from the environment by the significant lunar gravity. The chances of something getting by the bumper pane and penetrating all the window panes proper are not significant within the expected lifetime of the building. Sooner or later a window-invited meteorite decompression will occur, but it will be properly seen as a freak. If one or more panes are fiberglass reinforced, as suggested, the leak rate should be slow enough to allow escape and/or hasty repair and/or automatic pressure-drop-triggered plugging.



KEY: a) restricted field of view enforced by shielding set-back = restricted vulnerability both to cosmic radiation and micrometeorites; b) shielding retainer structure; c) regolith fill for shielding; d) visual quality shatter-resistant easy-in/ easy-out micrometeorite bumper pane; e) sealed multipane unit; f) detail of window unit blown up, next illustration.



KEY: 1) = 1/3 interior pressure; 2) = 2/3 interior pressure. This stepped pressure system relieves stress. The gas between the panes could be something other than air such as argon harvested from the lunar regolith. The sealed multipane unit is fastened in place simply by the graduated air pressure increases on the continuous perimeter gaskets.

I would be much more worried about exposure to cosmic radiation even from the very restricted portion of the sky accessed by such windows. I certainly would not design a direct-path window (as opposed to a broken path or periscopic one) in a residence. I included them in the design of possible lunar skyscrapers only in the intention that the pattern of use of such buildings, or of the rooms endowed with "windows", be such that the accumulated exposure of any given individual be within tolerable limits. Lunar pioneers may all have wrist or necklace accumulative "rad monitors" that will tell them when to tighten up their exposure patterns.

PK

MMReview #12 - January 1993

"Railroading on the Moon"

A Design & Design Exercise

© 1993 By [Peter Kokh](#), Doug Armstrong (both Copernicus Construction Co., Milwaukee), Michael Thomas (Seattle), Bill Bogen (Ann Arbor), Charlie Moore (Mokena, IL), and Andy Reynolds (Rochelle, IL)

Foreword

In a one column front page piece in Moon Miners' Review # 12, January '93, "RAILROADS on the Moon?", we wondered out loud if someday the degree of development on the Moon would reach a level of population and multi-site dispersal wherein, "in one or more specific surface traffic corridors the volume or raw materials, manufactured goods, or passengers might most efficiently move by rail or some such analogous path-slaved system." We pointed out some of the engineering hurdles that conditions unique to the Moon would place in the way of realizing any such system, specifically the extreme dayspan-nightspace thermal range to which exposed rails would be subjected, and the need to design out any possibility of catastrophic derailment.

We mentioned we had some initial ideas on how we might address such challenges and invited readers to send in their ideas. Several people responded, as you can see from the shared byline above. The exchange between Kokh and Armstrong, meeting in Milwaukee, and MMM Contributing Editor Michael Thomas in Seattle was especially frequent and voluminous. To all those who shared their thoughts with us, many thanks.

Our goal was not to "define" how lunar railroading might someday evolve. That would be presumptuous — there are too many ifs both with respect to the pace of lunar development and with respect to unforeseen technology developments which will almost certainly bear upon the question. Rather, we have attempted to flush out the options that we can see from this point in time. If and when the day comes where something of the sort is realized, some of our suggestions are bound to appear quaint and naive in retrospect. That's an occupational hazard of futurecasting! But we do this for fun.

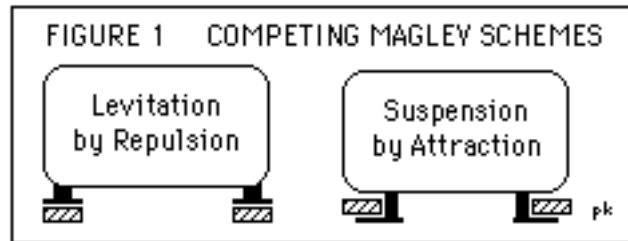
As we proceed, keep in mind the limited alternative options there are to lunar railroading: travel by surface coach or truck rig over improved graded-paved 'roads' or unimproved trails; travel by sub-orbital hoppers or rocket shuttles. Period. No atmosphere means no aviation. It is both air travel and the development of a first class network of fast express interstate highways which have brought about the

decline of King Rail from the unquestioned ascendancy it had prior to the end of WWII. On the Moon, it could be a whole new story.

CONVENTIONAL OR MAG-LEV?

One of the forward looking solutions that presented itself to several of us is Mag-lev rail in which the rail car hovers over a track, levitated by magnetic forces. This is an especially attractive option for long-distance passenger travel on the Moon. With no right-of-way problems and no atmospheric drag, pressurized cabins as large and wide as or larger than those of 747s could whisk travelers between far-flung settlements in vibrationless comfort at speeds comparable to today's terrestrial airliners. For non-urgent freight, 'conventional' traction railroading solutions might be more cost-effective. But first let us look at Mag-lev.

Two basic approaches are available. In the Japanese System, the superconducting 'ski' of the vehicle is levitated just above the rail by electromagnetic repulsion. In the German system, the superconducting guide plate of the vehicle is suspended just below the rail, held by electromagnetic attraction. [FIGURE 1]



Bill Bogen contributed a sketch of a Maglev car whizzing along across the moonscape. His proposed LunaRail system boasts a number of innovative features. "Bulldozers, graders, and rollers prepare a smooth path over the regolith. Roughly a megaton of Luna-derived aluminum is formed into thin, wide, 'V'-shaped rails for a Maglev train system [below]. * Image awaiting scanner

Besides carrying vehicles, the rails also carry the electricity needed to power the system. This electricity is generated by amorphous silicon solar cells that are integral with the rails, using the aluminum as substrate. Which side of the rail carries the cells depends on the orientation of that rail segment to the sun. The Maglev vehicles pass right over the solar cells, their magnetic fields penetrating through to the aluminum rail below. Given the large day/night temperature differences, we'd need about a 1 inch gap per 10 feet of rail (nightspan) to allow for thermal expansion (the segments almost touching during the dayspan). Flexible accordion connectors join the segments, allowing uninterrupted power flow. [below] Since the 'wheel' of a Maglev is more like a wide ski 'contacting' the rail over a significant area, such gaps would have little effect, assuming proper alignment."

"The rails circle the Moon roughly parallel to, but not necessarily near, the equator, though there may be other lines running to the poles or other regions of interest. Half of the system is in sunlight at all times so LunaRail also acts as a grid that provides power to communities during the 14 day lunar night. Supplying 1 million Lunans with 1 Kw each requires a minimum capacity of 1000 Mw. Since the rails provide power and each vehicle carries its own set of Maglev lift/drive components, there is no need for a separate engine car, eliminating the need for a 'train' [of cars] or the need to connect them. ... The LunaRail track could also serve as a launch-assist system, using 70 Mw to accelerate a payload at 3 g for 81 seconds to an escape velocity of 5,355 mph in a distance of about 60 miles."

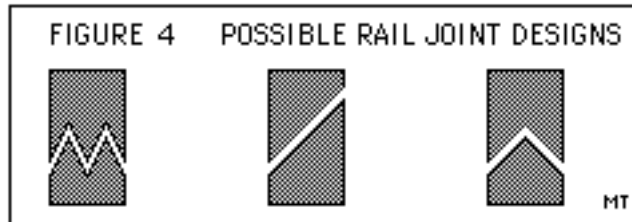
Several comments: a) If iron or steel rails are needed as part of a Maglev setup, there is plenty of free iron available in the regolith and a V-shaped iron rail could be loosely sandwiched to the power-carrying aluminum layer (which has a different rate of thermal expansion). b) While aluminum is a good carrier of electricity, line losses over any real distance (hundreds of miles) would be unacceptably great, so that (without superconductivity – see MMM # 66 JUL '93 "SUPERCONDUCTIVITY ON THE MOON, Uses and Obstacles" pp. 5-6) it would be quite impractical to use sunlight over the section currently in dayspan to power the section currently in nightspan. Nuclear or other assist would be needed. c) Power assured by whatever means of generation and transmission, if the superconductor needed for levitation is aboard the vehicle, not squandered along the entire length of track, such a system might still be feasible in the likelihood that an all-lunar formula for superconducting cable or rail is never found.

'CONVENTIONAL' SYSTEMS

PROBLEM ONE: THE CHALLENGE OF THERMAL EXPANSION

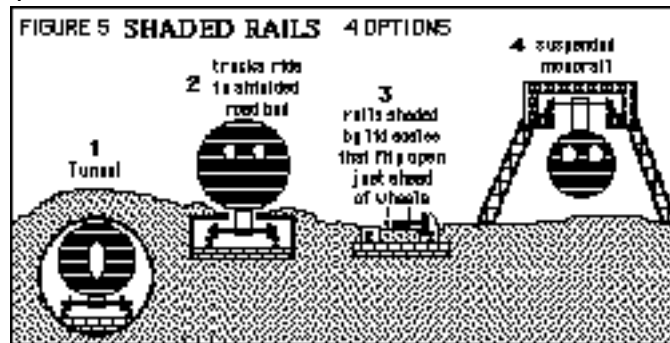
While Maglev speed will be most desirable, 'conventional' systems not involving superconductivity may be easier and cheaper to implement, certainly in the earlier period, and may do an adequate job, not only for freight but for high speed passenger traffic. On Earth, system planners are abandoning Maglev dreams for high speed rail almost everywhere, trading a little extra speed for lots of upfront savings cost. Much of the expense in implementing Maglev systems, to be honest, comes with the need to acquire all new Rights-of-Way. On the Moon, this is not a problem and the choice will be made on other grounds.

The first challenge to be met with conventional rail is the need to either permanently shade the rails or to provide thermal expansion joints (gaps) that are either undesirably large, undesirably frequent, or both. Michael Thomas has contributed three rail expansion joint designs.

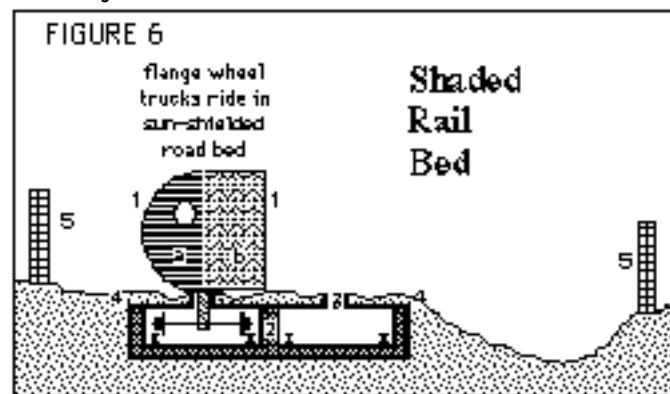


The problem with this approach is that rail gaps, just as rail joint misalignments, translates to the annoying and typical "klickety-klack". Even on the airless, soundless Moon where such sounds would not be 'heard', the accompanying vibrations would be felt. Today's designers of high speed rail are welding together ever longer lengths of rail – an approach not feasible for exposed rails on the lunar barrenscapes.

For this reason, Kokh and Armstrong propose shading the rails from the sun at all times so that expansion is not a problem and continuous unbroken rails for smooth, very high speed travel are feasible. In this system conventional flange wheel trucks would ride in a boxed sun-shielded road bed with an as-narrow-as-possible median slit for the axle to car suspension system. No moving parts would be required for this shading system.



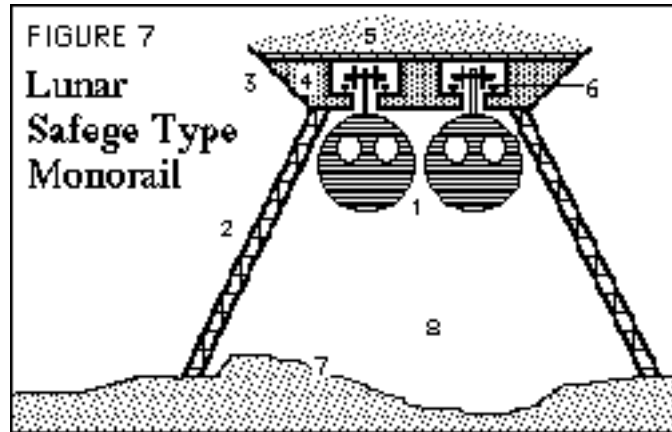
An earlier effort to design a system in which the two rails were individually trenched and shaded by a system of movable 'scales' was rejected as too vulnerable to mechanical failure from dust, for example.



KEY: (1) Passenger a) or Freight Car b); (2) Lunar concrete in steel alloy frame dual shaded rail bed, with welded rails for high speed; (3) Minimal sun-exposed slit for car suspension; (4) well-graded right of

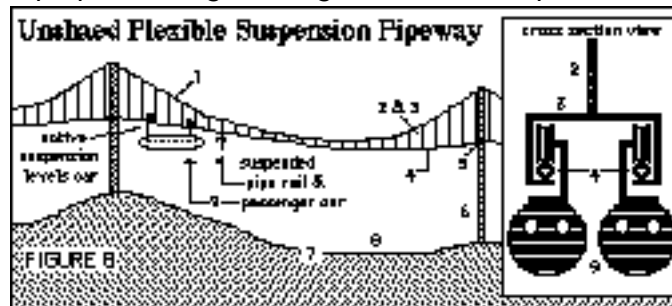
way; (5) right of way fencing. are a more expensive option, to be used, as on Earth, to shorten routes through mountain ridges and crater ramparts.

Two other alternatives were looked at. A Lunar "Safege" Type Monorail in which the cars are suspended below a shading track (as at Wuppertal, Germany) rather than supported above it in the familiar Alweg Type systems used in Seattle and Disneyland, etc. [below] While such a system would involve significant overhead construction, it would not directly require any surface grading (except to provide the materials for the overhead superstructure), and it would provide no obstacles for surface cross-traffic by maintaining continuous grade separation. We might see such a monorail favored for short distance passenger traffic, especially in built-up areas where maintaining grade separation between rail and surface traffic is a prime consideration.



KEY: (1) Passing Passenger Cars; (2) Support Pylons every 50 m or yds; (3) lunar steel alloy framework; (4) lunar concrete for thermal mass; (5) loose regolith fill for thermal insulation; (6) shaded welded rails; (7) minimally graded terrain; (8) grade separation clearance for surface cross traffic.

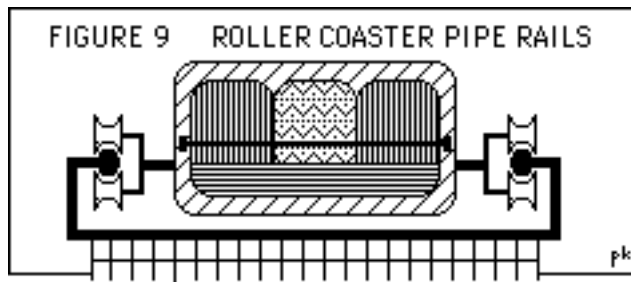
A simpler and less expensive system, a 'monopipe' rather than 'monorail' would suspend the vehicle car from unshaded cables or pipes free to expand and contract at dawn and sunset. The up and down valleys and peaks of such a flexible cableway would be greatly minimized by using a suspension system tied to an overhead supporting cable. [below]. Systems of this sort would do fine at more leisurely speeds and be a cheap option in sightseeing areas for example.



KEY: (1) Suspension Cable; (2) Pipeway Support Cables; (3) Pipe Support Brackets; (4) flexible piperail; with 42 cm (16.5") expansion between Pylons for 0.35 cm (1/7th") vertical droop differential; (5) Piperail floats free at (6) Pylons spaced every 50 m or yds; (7) minimally graded right of way; (8) Surface vehicle cross traffic clearance; (9) Passenger Cars (passing).

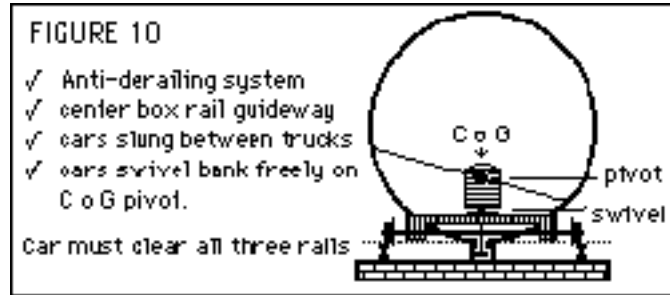
PROBLEM TWO: THE NEED FOR DERAILMENT PROOF SYSTEMS

On Earth, derailments are expensive in property damage and, in the case of passenger trains, potentially dangerous to human life. On the Moon you can delete the words "potentially dangerous" and replace them with "almost certainly fatal". A derailed car would almost certainly have its pressure hull compromised, quickly losing life-sustaining air to the external lunar vacuum. In short, the possibility of derailment must be designed out of the system. Both Michael Thomas and Charlie Moore pointed out that amusement park roller coasters use systems in which wheels are paired or even clustered around a tubular track so that the car CANNOT leave the tracks.

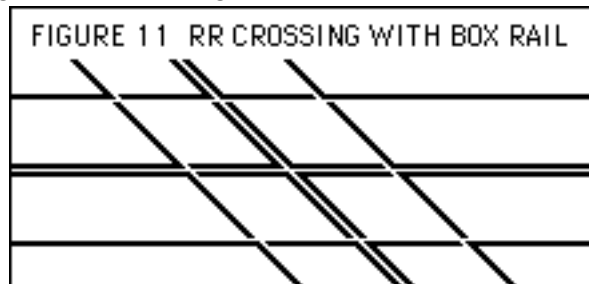


The unquestioned safety aspects of such schemes aside, there is a major engineering drawback to them. It is difficult, if not impossible, to design affordable easy-to-operate routine track switching and crossing for such pipe rail hugging systems because the wheel clearance gaps they would require would be too large for the small wheels used to negotiate. As for non-conventional systems mentioned above, a negative center of gravity (i.e. below the rail) is built into the monorail and suspensionway option. The monorail is inherently derailment-proof. The suspensionway is inherently derailment-resistant.

To meet both switching and safety needs, Kokh and Armstrong then proposed a "Center Box Rail" system in which a restraining bar, plate, flange, or pair of small wheels would ordinarily float free of contact. If the car 'started' to lift off one rail and threaten to leave the track, the center restraining bar would come into contact with the slit top of the center box rail.

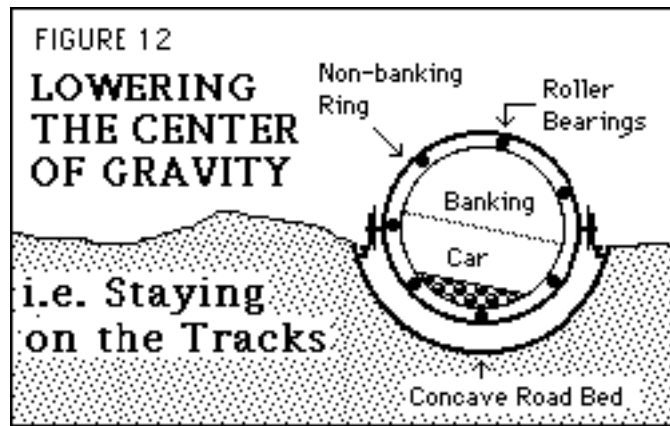


NOTE: In this illustration, the design is maximized for minimum center of gravity and anti-derailment strength. It does not take into consideration the need to shade rails. This third rail would lie in the same plane as the other two and its median slit need be no wider than the clearance needed for the side wheel flanges, making even grade RR crossings a simple matter.

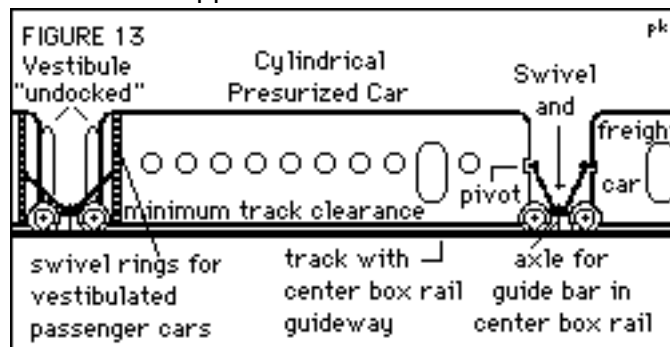


NOTE: In this illustration, the minimal gaps needed for conventional flange wheels and for the restraining device in the center box rail are shown.

An alternative proposal of ours was to suspend the rail car from the waist in a concave trough so that its center of gravity was actually lower than the side rails. The car's suspension would include flotation rings that would allow it to bank freely. The trouble with this idea is that it would again make switching difficult.



In another attempt to design a low center of gravity derailment-resistant system, we borrowed the Spanish idea of putting the wheel trucks between the cars, not under them, so that the cars could maintain minimal clearance with the rails. Again, this system would not combine well with our shaded rail bed idea, but would work in tunnel applications or under continuous shade sheds or ramadas.



In the back and forth exchange of ideas that made this effort a lot of fun, Michael Thomas took pains to elaborate the possible applications of all these ideas and came up with a number of interesting sketches of which three which show the breadth of his design search are given below. In FIGURE 14, Mike has combined the advantages of the shaded rail concept with those of the center box rail restraint system and come up with a "Flat Bed Quad-Rail". It introduces the idea that rails 'above' the wheels can be used to constrain the train's motion. A second upper set of wheels is desirable because wheels coming into contact with the upper rail need to turn or free-wheel in a direction opposite those riding the lower rail.

* FIGURE 14: A FLAT BED QUAD-RAIL (to be scanned)

NOTE: The size of the wheels is greatly exaggerated to show the arrangement in more detail.

KEY:

- 1) Concrete or Ceramic overhang and rail support.
- 2) Upper rails for inside-flanged wheels
- 3) Upper wheel with inside flange
- 4) Lower wheel with outside flange
- 5) Inter-carriage wheel truck
- 6) Pressurized car
- 7) Pivot attachment point to wheel truck.
- 8) Lower rails for outside flanged wheels)

In FIGURE 15, he uses the same "quad rail" restraining concept together with a concave road bed and overhead shading.

FIGURE 15: A CONCAVE BED QUAD-RAIL (to be scanned)

KEY: Same as for Figure 14 above.

FIGURE 16: (to be scanned)

In FIGURE 16, Thomas depicts an extra wide road bed with a center box rail support together with lowering the ratio of the center of gravity to the track width by supporting two cars side by side on a single double width chassis. Shading is provided by a lightweight arch shed built of lunar concrete blocks.

In last analysis, the simplest, most elegant, most cost effective designs will win out. Some solutions that we have not foreseen are sure to surface in the future with the introduction of new technology.

CONCEPT OF THE "TRAIN", SEVERAL CARS LINKED TOGETHER

In terrestrial passenger trains, we are accustomed to being able to walk the length of the train, from one car into the next, without being exposed to the elements, thanks to flexible accordion like "vestibules" linking the cars. In lunar conditions, not only shelter but pressurization against the external vacuum must be maintained, and this would be difficult to manage with a flexible system constantly bending up, down, left, right – difficult, but not impossible. After all, the spacesuit joint manages the same task fairly well. Yet no spacesuit has undergone the 'mileage' of constant use to which rail equipment must be subjected.

"Vestibulated trains" may be an unlikely denizen of future lunar travelways. Instead, given both the economic possibility of much wider Rights of Way, and consequently of much wider track gauges, and the lack of the need for streamlining against air resistance, plus the lower gravity on the lunar surface, single double and triple width, double and triple decker, and double and triple length rail cars are feasible – more on a par with today's Boeing 747 cabin than what we are now used to riding on the rails. This will hold of both conventional rail systems, overhead monorails, and Maglevs alike – as the traffic volume warrants.

On the other hand, as we attempted to illustrate in FIGURE 13, we might see instead a "train" of more conventionally sized cars, all equipped with vestibules which, however, would be undocked with one another while the train is in motion, but "dock" together when the train is standing motionless in the depot on straight and level track. This would allow boarding and unboarding through the end car (trains backing into the depot) instead of requiring a series of docking ports, one for each car's side port.

LOCOMOTIVE POWER OPTIONS

We were unquestionably more preoccupied with the design challenges tackled above than with the question of motive power for lunar trains. After all, the options here seemed to be more clear, less in need of brainstorming. Rails could be electrified, the power coming from a combination of trackside solar arrays and solar power satellite in the L4 and L5 Lunar co-orbital fields and/or from nuclear(or thermonuclear i.e. He-3 fusion) plants. An all-lunar formula for superconducting cable would certainly help but seems at this juncture unlikely. An alternative would be to use satellite-laser-beamed power directly to individual rail cars and trains.

In the honeymoon days of nuclear power (yes, youngsters, there was such an era us oldsters dimly recall), the coal-dependent Norfolk and Western seriously considered a nuclear powered locomotive. After all, weren't nuclear reactors being put aboard submarines? If the shielding problems can be solved to everyone's satisfaction, this could be a sleeper option. A more remote sleeper is onboard fusion power. At this time we don't have a high degree of confidence nuclear fusion can be engineered at all. It is quite premature, then, to speculate how compactly He-3 fueled locomotive power packs could be built. The advantage would be that, in contrast to conventional nukes, they would need little or no shielding, a very attractive prospect.

To many, our nation's space program being industriously disassembled before our very eyes by a Congress and Administration preoccupied with other priorities, the idea of railroading on the Moon must seem sheer folly, unrestrained fantasy. But the government could never open the Moon anyhow, so these setbacks are irrelevant. If the Lunar Resources Data Purchases Act is passed, and our expectations about exploitable lunar resources are borne out, and as Earth's energy options dwindle and environmental constraints tighten, we WILL return to the Moon with or without government help or approval, out of sheer economic necessity. That is the only motive worth considering and boosting – yet the one most neglected by space advocates.

Once we clearly HAVE TO go back, and do so, the pace of economic development on the Moon, and in space in general will explode far beyond what almost anyone dares dream today. Someday there WILL be thousands of people on the Moon, not a mere token elite handful, THEN hundreds of thousands. It will be in such an era that LunaRail lays its first stretch of track, bound for a future with much less competition than rail has had here on Earth.

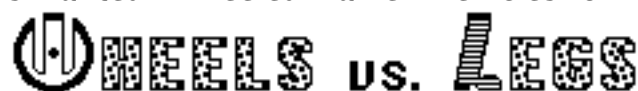
Thanks again to all who took part in this first round of brainstorming on this question. Those of you who didn't participate but now have something to add to the discussion, are certainly welcome to do so. Just [write](#) to MMM/MMR c/o the LRS P.O. Box 2102, Milwaukee, WI 53201-2102.

Subsequent Brainstorming by Peter Kokh and Dave Dietzler has concentrated on these issues:

1. **Finding the right lunar–producible alloy for the rails**, with minimal coefficient of expansion and contraction with heating and cooling; One option we began looking into in 2012 was the possibility of making rails from basalt–fiber composites, now used to make “rockbar” which is rapidly replacing steel rebar as a reinforcement for concrete structures. This could remove the previously perceived need to shade the rails, for which we had come up with a number of options, all of them costly.
2. **“Right of way” and track gauge:** As right of way and land acquisition is not a cost–consideration on the currently empty Moon, there seems no reason not to go with a very wide track gauge, which would lower the center of gravity, and allow single very large passenger and freight cars. If we did have “trains” that is a number of inter–connected cars, vestibulation would be tricky, if pressurization is to be achieved. We could simply allow passage between cars only when the train is in a station, on a straight track segment. That also means that overhead clearance for trains could be set quite high to allow for two or more deck units. The cheapest option for crossings would have roadways for automobiles and trucks, dip under the rails.
3. The large gauge and clearance would allow rail cars to ship large modular housing and other units.
4. Railroads could be the main means of spreading out the population to new settlements and outposts along the route.
5. Railroads on the Moon would be ideal for shipping industrial goods and components as well as ores.
6. With aviation out of the question, lunar railroads, including hi–speed MagLev trains, would become the glue that holds this new world together.
7. There is no need for “streamlining”

MMM #62 – February 1993

[Inventors Wanted: “Wheeled Walker” vehicles for The Moon]



for Extraterrestrial Transport

WHEELS VS. LEGS By P. Douglas Reeder, Oregon L5

(also submitted to [StarSeed](#))

Comparison of existing models leads one to the conclusion that mechanical legged vehicles are not worth serious consideration for land transport on other worlds. However, consideration of the fundamental mechanics and energetics of locomotion and the capabilities of legged animals leads to a different conclusion.

Although existing legged robots are slow, it should be noted that horses can carry a human at dozens of kilometers per hour for long periods, using one horsepower. Automobile engines generate hundreds of horsepower, plenty for a car sized vehicle if it has adequate energy efficiency, about which see below. As to control at high speed, cheetahs travel up to 120 km/hr over broken terrain. Mechanical legged vehicles with electronic control should be able to do at least as well.

All vehicles expend energy to raise the weight of the vehicle against gravity when ascending large terrain features. Properly designed vehicles can recover some of this energy when they descend. However, regenerative braking systems are still experimental for wheeled vehicles and research has barely begun on downhill walking.

Both wheeled and legged vehicles expend energy to accelerate the vehicle body. A rough ride, aside from being hard on passengers and cargo, wastes the energy that is used to accelerate the body in directions other than the direction of travel. Legged vehicles have the potential for a smoother ride at all velocities, but it is not clear whether this produces a significant energy saving. A wheeled vehicle must climb over an obstacle all at once, requiring high peak power. Legged vehicles can move one leg at a time, if necessary, using a smaller, lighter power plant.

Wheeled vehicles use energy to angularly accelerate their drive train and wheels, which uses little energy for usual designs. (The rover designs that are mostly wheel use much more.) Legged vehicles must accelerate their legs. On level ground, the legs oscillate in regular patterns and a properly designed mobile (such as most mammals) expends little energy to keep the oscillations going, but much more than comparable wheeled vehicles. Current mechanical walkers dissipate the leg kinetic energy at each stroke, and much more research needs to be done in this area. On rough ground, the irregular patterns of leg motion increase the energy loss significantly at high speeds, so picking one's way across a boulder field is not just safer, it is more efficient as well. Energy dissipated in leg/wheel motion is the area where wheeled vehicles do significantly better.

Soil interaction is where legs do much better. On soft ground, wheels compact the soil ahead of the wheel, expending energy to dig a rut in the ground. Wheeled vehicles are continually climbing out of their own rut (on soft soil), reducing their traction. As a leg pushes back, the soil behind the foot is compacted, increasing traction. Hard ground reduces the penalty to wheels, but this usually requires prior paving or rail-laying, at great expense, and is only economic for high traffic corridors – common on Earth and nonexistent elsewhere.

In summary, properly designed legged vehicles can offer efficiencies within an order of magnitude of wheeled vehicles on smooth, paved surfaces and do better than wheels on rough terrain.

Where are these properly designed legged vehicles? They don't exist (yet). Serious research on mechanical legged vehicles is less than two decades old, while the automobile has been in development for almost a century, and wheeled vehicles for millennia. Animals demonstrate excellent mobility and good efficiency for their materials. With higher-strength material, higher energy densities, and the speed of electronics, we should be able to do at least as well, if not better, than protoplasm technology. In addition, mechanical walkers do not need to be fed when not working, can run all day and all night, and do not have desires of their own.

The most efficient and practical legged vehicle so far is the Ohio State Adaptive Suspension Vehicle (ASV) massing 1700 kg and carries a 220 kg payload at up to 13 km/hr. It is powered by a modified motorcycle engine.

Outlook for Legged Vehicles

On Earth, legged vehicles will find a niche, but will not replace wheels and roads and rails. We have a great investment in wheel technology and our society is set up around it. In addition, population is high and transportation routes are heavily used.

On the Moon, Mars, and other bodies, the reverse is true: we have no infrastructure of roads and rails, and travel densities will be low for a long time. If suitable legged vehicles are available by the time colonization is starting, colonies can be designed around the use of legs instead of wheels. What would be different? Primarily, you don't need to pave anything. No unsightly and expensive roads and parking lots. Trails need only be cleared of the largest boulders and can ascend steeper slopes than are practical for roads.

Wheeled off-road vehicles and rovers also eliminate the need for roads, but offer a much rougher ride which is hard on people (reducing the amount of work they can do) and on delicate scientific gear. Legged machines still need bridges for gaps larger than a few meters. (Ohio State's ASV can cross trenches up to 2.7 meters and climb cliffs up to 2.1 meters, capabilities far beyond that of any wheeled vehicle.)

A legged vehicles can carry heavy equipment right up to its final location whether that is in a canyon or on top of a mountain, and hold it level! You don't need to drive a road to a site before you develop it. Boulders falling on a trail for legged vehicles don't block the trail, but merely it to the side.

Legged vehicles are mechanically more complex, and probably will require more maintenance than wheeled vehicles. You won't have two lanes of traffic going opposite directions within a meter of each other, almost eliminating vehicle collisions. An interesting visual effect is that a large expedition

would resemble a stampede with diesel engine sounds. A good thing there isn't any local fauna to terrify!

Legged vehicle travel will follow natural routes across mountains (valleys, ridges, passes) but on the plains travelers will head straight for their destination, instead of along the road grid we use on Earth. Putting up a fence and saying NO TRESPASSING might be considered downright hostile.

You could drive your legged truck right into the middle of the greenhouse to load it, with it carefully stepping on the walkways, Feet do far less damage to soft ground and vegetation than wheels, reducing erosion, and kick up less dust in dry soils. Legged vehicles offer the potential to significantly impact the way other planets are explored and developed.

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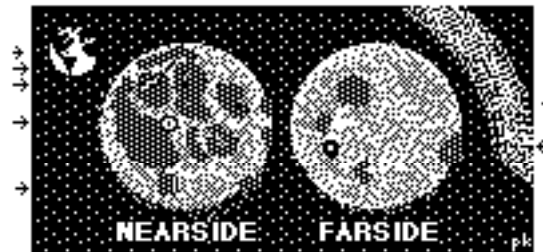
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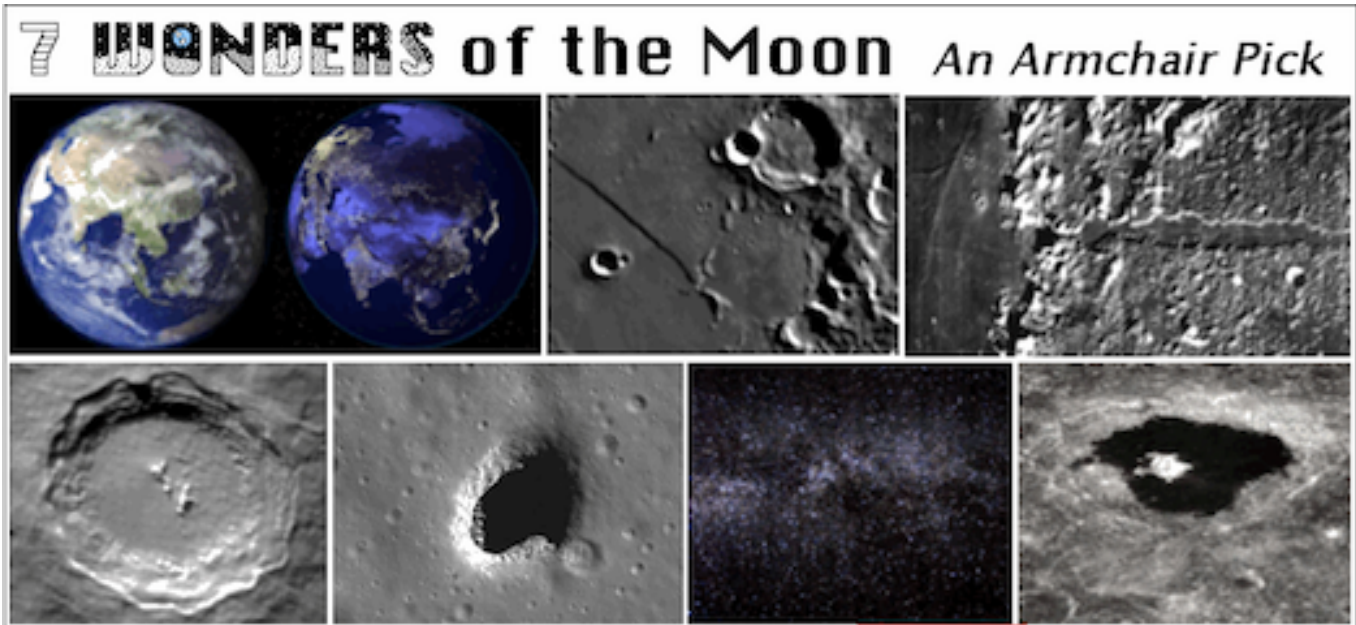
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MMM #69 – October 1993



“Must See” Sights for Tourists on the Moon

Anyone coming to the Moon will see and experience quite a bit, enough to acquire a lifetime of memories, just in the landing and departure process and in the short taxi from the pad to the settlement airlocks — without having to go out on special expensive surface excursions. All the same, it would be a shame to make a half million mile round trip without getting to see up close a typical range of Moon-scape terrain, and if possible, at least some of the best this world has to offer. See “7 Wonders of the Moon” below.



7 WONDERS OF THE MOON

By Peter Kokh

From orbit, as through any modest telescope, it will be quickly apparent that the Moon offers an unexpectedly diverse landscape. Eye-catching paintings of over-imaginative artists aside (there are no craggy peaks untouched by erosion and few if any rough edges — all terrain features having been inexorably softened by the eons-long rain of micro-meteorites) this world does have some striking features all the same.

On Earth the rugged awesomeness of crustal rock outcrops and other features forged by a contest between brute geological forces and the relentless onslaughts of an ever active weather system are set in contrast to the beauty of vegetation in wild strobe-like stasis of species competing for niche space. On the sterile and barren Moon there is no such counter-play between geological awe and botanical beauty. Moonscapes, however otherwise dramatic or boring in feature, are all of one canvas in being displays of “magnificent desolation” (Buzz Aldrin, Apollo 11 landing crew, 7/20/’69).

Many humans are quite insensitive to natural beauty (e.g. “when you’ve seen one waterfall, mountain etc., you’ve seen them all.”) and will react to the Moon in character: “when you’ve seen one crater, you’ve seen them all”. To those of us with an eye for differences and especially to those of us with an appreciation of untamed geological drama, the Moon, which bores only the boring, can boast a wealth of spectacular vistas.

As on Earth, the most spectacular views of the terrain itself will be had from the unobstructed vantage points of high ground — from crater and ridge tops, mountain peaks, rille edges, and promontory points. These overlook craters and walled plains, the frozen lava seas of the maria, straight and sinuous valleys, rolling, cratered, and chaotic terrain etc. As on Earth, there will be sights that merit only local or regional fame, and those that deserve a place on the global honors list.

Here is an armchair selection of nominees for a place on the “Seven Wonders of the Moon” list, the pick of one Earth-bound, telescope-, moonglobe-, and lunar photographic atlas-equipped student of the surface of “Earth’s significant other”. Only five of the Wonders on the list are surface features. Two spots are saved for extra special treats in the lunar heavens.

Five Nearside Wonders of the Moon

1. Earth itself, an apparition in lunar nearside heavens with 3 1/2 times the breadth, blocking out 13 times as much of the starry skies, and shining with 60 times as much glaring brilliance as does the Moon as seen from Earth — all in a spinning ever changing marbled riot of blues, greens, browns, and whites. It goes through the same series of sunlit, night-darkened phases as does the Moon in our skies — with spectacular differences. “New Earth” when eclipsing the Sun during what we interpret as a Lunar Eclipse is a dark circle in the heavens crowned with the fiery ring of the sunset-sunrise line as sunlight scatters in the dust of the atmosphere. The night-darkened portion of the globe is in the last century increasingly “star-studded” with the city lights of burgeoning urban areas and oil and gas field burnoffs of “waste” natural gas and hydrogen. Meanwhile the frequent reflection of the Sun off ocean and ice accentuates the sunlit portions.

Full Earth illuminates moonscapes with sixty-some times as much brilliance as Full Moon brightens Earthscapes. This will be handy for getting about during the long lunar nights. But without a dust and water vapor laden atmosphere on the Moon, Earthshine shadows are inky black and impenetrable, and starlight is not drowned out. However, for the eye’s pupils to open enough to appreciate the starry vistas, the brilliance of Earth must be baffled out of one’s field of vision.

While Earthbound students can patiently study a seemingly eternally changeless Moon, lunar settlers and visitors who turn their gaze upon the Earth will have an unending drama of spectacular kaleidoscopic change to admire and study. It will be a treat without the distraction of flora and fauna and weather in the foreground, a Van Goghish canvas of color understatingly matted by black sky and gray regolith.

Astronomical painters such as Bonestel have tried to help us envision what it will be like to look upon Mars and the various other planets from the surfaces of their natural satellites. But the view from the Moon need take second place to none. Yet not all lunar settlers and visitors will be able to appreciate it with equal ease.

To paraphrase the opening sentence in Caesar’s report on the Gallic Wars, “Omnis Luna in quatuor partibus divisa est”: “All the Moon can be divided into four parts”.

In the central part of the Nearside hemisphere, Earth is either directly overhead or at a very uncomfortable high angle above the horizon. Settlers might aptly nickname these central regions “**The Crooknecks**,” Included is most of Mare Imbrium, Mare Nectaris, Mare Serenitatis, Mare Tranquillitatis, Mare Nectaris, Mare Vaporum, etc.

“**The Postcardlands**” are the peripheral portions of nearside, regions in which the Earth hovers perpetually a comfortable 5–40° above the horizon.

Adjacent to these, straddling the “limb” of the lunar globe which forever keeps the same side turned towards Earth are “**The Peek-a-boos**”. Because the Moon’s axis is not perpendicular to its orbit around the Earth and because that orbit is somewhat eccentric and the Moon travels faster when nearer Earth and slower when further away, all the while rotating at a fixed rate, about 7° to either side of the 90° East and 90° West lines are alternately turned towards Earth and away from Earth. Together the above three regions cover nearly 60% of the lunar surface.

The remaining 40+% is in “**The Obliviside**”, the Farside heartland from which Earth is never visible. This fact sets the scene for the last two Wonders on our list.

2. Copernicus. Nearside has many striking large craters. Any amateur astronomer who studies the Moon through a backyard telescope will recognize a couple dozen by location, appearance, and name. And each will have his/her favorites.

Even to the naked eye a few craters stand out a quarter million miles away. During Full Moon, **Tycho** in the mid-south is the radiant point of bright streaks of lighter regolith splash-out that stretch for thousands of miles. Smaller **Aristarchus** catches one’s attention with the superimposed brilliance of Venus. **Plato’s** dark floor (Academy Plain?) can be picked out just north of Mare Imbrium, the Sea of Rains.

Through the binoculars even more can be recognized. But even though there are sixty-some other nearside craters as large or larger, easily the most striking of all, from Earth, is **Copernicus**. With its extensive debris slopes, it sits alone in southern Oceanus Procellarum, the Ocean of Storms, without neighboring rivals. **Mount Nicolaus*** at its center reveals a glory of detail. [* The author has published his suggestion that crater central peaks be known by the first name of the famous person after whom the host crater is named. They are otherwise known only as “central peak of ...”] A stunning low angle photomosaic of Copernicus taken by Lunar Orbiter 2 in late ‘66 was billed by the media as the “Photo of the Century”. Indeed its psychological impact was without precedent.

Early settlers will have as favorites prominent craters that lie in easy excursion reach of their settlement site. And it will be these that are first offered on itineraries of tourists from Earth. As tourist support infrastructure grows, however, those sights with world-class splendor will be offered. If Copernicus is not handy to the initial settlement site(s), it will soon be reached “by beaten path” nonetheless. In low gravity “sixth-weight” it should be easy enough to build an elevator-equipped observation room-capped tourist tower 2 miles (10,000 ft., 3 km) high atop Copernicus north rim to showcase the scene.

3. The Straight Wall. In southern Mare Nubium, the Sea of Clouds, lies a 90 mile long escarpment or cliff known as “The Straight Wall”. Because it runs north and south, it is cast into high relief by the rising Sun and is very prominent in even a low-power scope a day after first quarter (first or waxing Half Moon). While the “wall” is not really that high, this sunrise shadow play can be appreciated from surface viewpoints as well, especially those above the average elevation of the plain to the east [a mischievous use canonized by astronomers. The thought never crossed their ivory tower minds that the orientation of people on the surface might someday matter. What is the “eastern” hemisphere of the Moon as seen from Earth is really the “western” hemisphere from a lunar point of view as determined by the progress of sunrise and sunset.]. This feature probably does not deserve a thousand mile detour, but it is unique and special enough to be on the itinerary if established trade and travel routes pass nearby.

4. The Alpine Valley. Running like a canal through the mountainous terrain between Mare Imbrium and Mare Frigoris a couple of hundred miles east of Plato is an arrow-straight cut or trench, probably made by a massive piece of ejecta from the impact explosion that carved out the Imbrium basin. About a hundred miles long, it is sure to be a mainline route for traffic and utility lines between these two mare areas. All along the route there are high points to either side which must offer quite a vista. Some of these may one day host tourist lookouts, rest stops, and hotels.

5. The lavatubes. While we have strong evidence such features exist and in what kind of lunar terrain we are likely to find them, we have yet to actually map, much less explore, even one. These cavernous wormholes made by subterranean rivers in the still cooling lava floods that, layer upon layer filled most

of the Moon's larger impact basins over three and a half billion years ago. Some near surface tubes have partially or wholly collapsed to form broken or continuous sinuous rille valleys. But many others must lie intact, invaluable geological preserves as well as handy shelter for the more volume-hungry needs of lunar settlement and industry. Lavatube exploration is sure to be an honored lunar "outlooks" activity.

Two Farside Wonders of the Moon

6. The Milky Way. One of the lesser recognized ways in which we are allowing our terrestrial environment to continue to degrade is urban nocturnal light pollution. Today there are millions of youth who have never seen the Milky Way. For those of us fortunate to live in or visit at least occasionally countryside areas well outside built-up populated areas, the sight of the Milky Way in dark star-bedazzled skies is unforgettable. But we glimpse it at the bottom of an wet and dusty atmospheric ocean. Even in mid-desert where on cold crisp nights the seeing is best, we are somewhat handicapped.

On the lunar surface, atmosphere is absent. But anywhere in the Nearside Crooknecks or Postcardlands, and part of the time in the Peekaboos, there is the distracting brilliance of Earthlight which must be baffled not only from view, but from reflection on one's helmet visor.

It is in Farside during nightspan, both Earth and Sun below the horizon, that the Milky Way shines in full undampened, unchallenged glory. To look up from such a vantage point and scan this river of star clouds as it arches across the heavens from horizon to horizon is a treat no human has yet experienced. For those with soul enough to appreciate it, this awesome sight will be a, for some the, reason to visit, or settle in, Farside. Many will choose the peripheral Peekaboos along the limb, for in these areas one can enjoy both the Milky Way, and Earthrise/Earthset, alternately.

7. Tsiolkovsky. The standard approach and landing trajectory that ships bearing settlers, tourists, and visitors will take to surface settlements will bring them in on a descent swing around Farside. Mare Orientalis, the dramatic bullseye-shaped Eastern Sea (misnamed because it is in the western Peekaboos) will be the feature most watched for, if, of course, it be sunlit at the moment. But deep in Farside, again depending on the time of sunth, another spectacle awaits them, to this writer's eye the most dramatic crater on the Moon — Tsiolkovsky, aptly named after he who taught us that Earth is but our cradle, and that it was our destiny to move up, out, and beyond.

Like Plato and Grimaldi on Nearside, Tsiolkovsky's basin is flooded with mare-like deposits — in its case some of the darkest mare regolith to be found anywhere on the Moon. This only serves to set off even more strikingly the **Mount Konstantin** massif that dominates Tsiolkovsky's interior. What a perch for a monastery or latter day shangri-la!

If the day comes when human settlements in the solar system organize in some politically cooperative way, what better site for a capital or headquarters than on Tsiolkovsky's dark flat floor south of the Konstantin massif. It is handy enough to Earth where most of humanity will continue to live for a long time to come. Yet its horizons face away from the hidden cradle world out upon a Milky Way crowned universe of unlimited opportunity. And who could pick a better name? It's frosting on the cake that those approaching from space could pick it out instantly by naked eye a half million miles out

National Parks and other Preserves

Any discussion of great natural wonders would be incomplete without considering what we might do to preserve such heritage. **Scenic Preserves** would establish regulations restricting buildings, road placement, and other developments in the foreground or background visible from scenic overlook sites. **Geological Preserves** would go further, protecting not only specific viewpoints but the physical feature itself from development, some types of mining, etc. Designation as a **National Park** would signify the intention to develop tourist and other recreational use facilities nearby so that the feature could be popularly enjoyed in a controlled fashion, as well as preserved from other types of development.

There is the added question of preservation of scenic orbital perspectives, i.e. of preventing developments that might be defacing on a large scale. Given the impotency of efforts to control forest clear-cutting in the Pacific Northwest where ugly scars that seem to grow cancerously insult anyone peering out an airplane window, lunar authorities will have to insulate themselves from the palm grease of developers if they are to have any luck. But solving the future's problems is the chore of those alive at the time. We can but warn.

MMM



FOR SALE: Unforgettable Experiences & Unequaled Opportunities

TOURIST EARNINGS By Peter Kokh

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

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

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

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

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

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

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

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

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

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

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

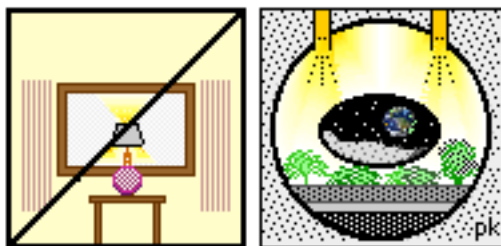
For sightseeing surface excursions, pressurized cabins retired from Earth-Moon ferries and fitted with wheeled chassies and suitable motor units ["toads", cf. MMM # 48 SEP '91 pp. 4-6 "Lunar Hostels: Part I: Amphibious Vehicles"] should be available as sleep-on go-anywhere coaches. They might be brightly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

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

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

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

MMM #76 – June 1994



Windows – out with one cliché, and in with another

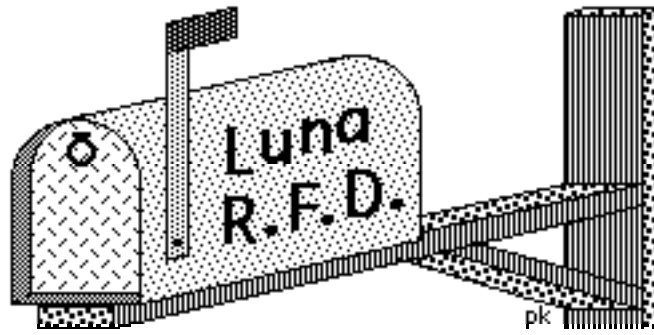
Driving along at night one sees home after home with a lamp on a table in front of the picture window? Poor decorating actually, but commonplace. On the Moon, with very little pedestrian or motor traffic "outside", exterior "presentation" will rate low.

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

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

MMM #79 – October 1994

MMM begins a New Series



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



RURAL LUNA Part I: Beating a Path

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

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



LUNAR ROADS By Peter Kokh

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

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

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

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

“Highways” beyond the Base/Settlement Perimeter

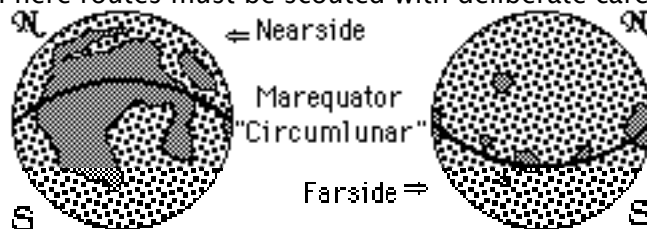
Away from the settled areas, dust control, while always helpful (reducing and simplifying vehicle maintenance) will be less important. Depending upon traffic volume, simple clearing of boulders and modest grading here and there may suffice over carefully surveyed routes. Rights of Way can be very generous,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

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

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

The “Circumlunar” Route L1

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



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

Scenic Highroutes

On Earth, “scenic” roads often hug terrain features such as valleys, shorelines, ridges and mountain crests. On the Moon, it will be no different. Routes chosen for the views they afford will wind along rille tops or bottoms, crater rims, and mare coastal ramparts, lava flow fronts etc. As they may well be more expensive to build, such roads will come later, multiplying step by step as the domestic and for-

eign terrestrial tourist traffic increases. For a long time, most tourists on the Moon will be settlers and others already living on the Moon.

Finding one's way, safely

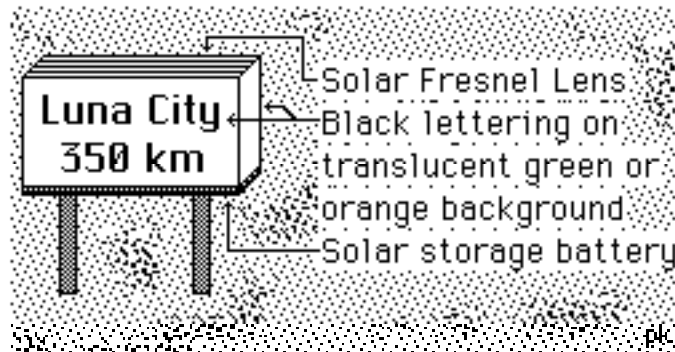
In addition to the constraints on choice of materials and construction methods posed by the extreme range between nightspan and dayspan temperatures, there is the challenge of the accompanying differences in illumination. In dayspan, the glare from reflected sunlight is intense. This is so despite the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

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

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

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

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



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

Not by sight alone ...

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

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

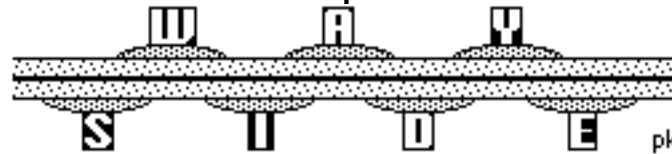
For entertainment and news on route, lunar radio stations could reach travelers by the above satellite relays. Antennas large enough to pick up signals from L4 or L5 could also bring in Earthside

stations. Conversely, terrestrial dishes big enough to pick up signals from L4 or 5, more than ten times the distance of geostationary comsats now in use, would be needed to eavesdrop on lunar programming, either direct or reboosted by relays in L4 and L5.

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

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

The Basic Automated Unpressurized Convenience



WAYSIDES By Peter Kokh

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

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

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

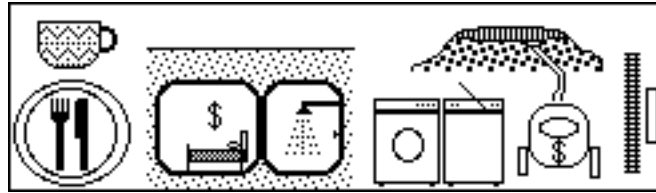
Such automated stations can be designed as compact units with modular pullout/plug-in changeable components. They could be trucked to the site overland, or delivered ahead of road-blazing crews to areas about to be opened by suborbital hopper or lunar all-terrain vehicles.

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

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

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

Service Centers & Inns



By Peter Kokh

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

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



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

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

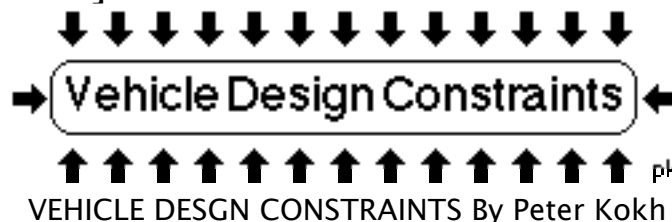
A lounge for guests to mix socially could complete any dining facilities. It could be stocked with an assortment of games. Besides a kitchen and meal service, there could be an in-room kitchenette, even picnic supplies for an outing in an attached solarium-arboretum-garden under a glass dome (total accumulative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

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

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

PKPKPK

[Lunar Roads, Part II:]



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

➤ **Dust Control** ➤ **“Dustlining”**

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

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

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

➤ **Saving atmospheric gases** ➤ **“Snuglocks”**

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

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

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

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

➤ **Ease of Maintenance** ➤ **“Modular Drive”**

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

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

➤ **Road worthiness** ➤ **“wide, low, shielded”**

The salient features of the lunar motoring environment in addition to its dustiness are the low 1/6th Earth-norm gravity or sixthweight, and vulnerability to occasional deadly solar flare storms. To tackle the first, the wheel units, vehicle outside the snuglock, should extend well to the side, reptile

style, rather than below, mammal style. Road lanes can be as obligingly large and accommodating as pragmatism demands.

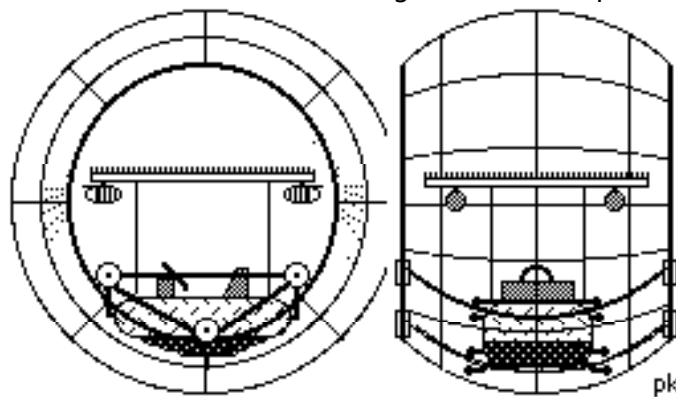
In addition, given the equally reduced traction, the center of gravity must be kept as low as possible, even though ground clearance may need to be generous, especially for off-road vehicles. In this latter case, a vehicle can ride low when the path is relatively level and boulder-free, then automatically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

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

MMM #81 – December 1994

Lunar “surrey with the fringe on top”

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



Similar solar powered spheres could be equipped with a track riding buggy capable of generous side-to-side movement or banking. Such an “off-road vehicle” – call it a unicycle, an auto-tracker, a cyclotrack, or whatever – could open the vast lunar barrenescapes to the sports-minded “outlocks” types and help avoid cabin fever. More on Lunar vehicles below.

[Series Continuation from MMM # 79, OCT ‘94]



Part II. Surface Vehicles & Transportation

Travel on the Moon, or Mars, won’t be as causal as on Earth for a long, long time to come. Nor will there ever be as many modes. On the Moon, air travel is not an option, and reliance on suborbital rocket powered hoppers would increase the strain on the quality of the vacuum, a unique industrial and scientific asset worth preserving at any cost and inconvenience. On Mars both of these options are open and viable. In this article, however, we are concerned with ground transport.

Getting from here to there over the lunar surface, or over the Martian surface for that matter, poses an interesting set of challenges. The most obvious of these, negotiating the trackless terrain, is the one that has received most attention. Innovative wheel/tire designs and terrain-hugging suspensions are what we have come to look for. In recent years with the exploration of the possibility of mi-

rorobotic rovers, walking contrivances and computer programs to operate them have been added to the repertoire.

A few years back, OMNI Magazine offered a \$500 prize for most innovative lunar rover design. Here too, the process of negotiating the terrain received the most attention. There have been some distracting bugaboos. For example, the OMNI requirements included a provision that the vehicle be able to handle crevasses. Sorry folks, but apart from the ice caps on Mars, "there ain't any"! At the same time, some very real, very salient challenges have received very little attention.

There is more to a vehicle than its interface with the ground! Other considerations need to be addressed:

✓ the temperature range over which the vehicle must operate: on the Moon, from 200 some degrees below to more than that above Zero Fahrenheit; on Mars, mostly in the colder part of this range. – Note that the Apollo rovers were operated only during the dayspan. This means special heat and cold-resistant lubricants must be formulated, perhaps that special bearings must be designed. It means that batteries and/or fuel cells must either be thermally well insulated or be designed to operate in extreme temperatures. Siliconized lubricants, super-conductive magnetic bearings, and thermally insulated power plants would all seem to be a part of the picture.

✓ The distance range over which the vehicle can operate without returning to base. Where time is not a consideration, a vehicle powered by solar arrays can operate continuously from shortly after sunrise to shortly before sunset some fourteen days later, then sleep through the two-week long nightspan. It's range is not limited. But except for robotic exploratory and/or drone freight vehicles, time is a consideration. Speeds must approach those the terrain will bear. And nightspan travel may well be required.

Solar arrays may be used as auxiliaries but stored electrical power such as fuel cells may be primary. Another option is chemical power using "fuels" derived from the surroundings on route, for example powdered pure iron fines extracted from the soil, burned in oxygen. To our knowledge, no one has as yet been thoughtful enough or inventive enough to attempt developing the engine required. Once we have such an engine, a refueling depot infrastructure will be needed to allow indefinite ranging.

Certainly, like it or not, for free ranging capability uncoupled to refueling depots or caches, nuclear electric motive power is a prime option, that is, if suitably sized lightweight yet full-shielded units can be engineered. But that will be quite an engineering challenge.

Yet another range-expanding option is beamed power.

BACKGROUND: For fleet vehicles operating in the immediate vicinity of a main base or settlement, power generated by whatever means can be beamed from a high tower to any non-occulted vehicle within a local range of several miles. [See the suggestion of Myles A. Mullikin in MMM # 31 DEC '89 "The Laser Power Tower" p. 5.] Such an arrangement could cover construction vehicles, delivery trucks, spaceport coaches, etc. The rooftop rectenna would be much lighter in weight than the alternative bank of fuel cells or batteries. While the beam could be adequately safeguarded by fail-safe feedback loops, the capacity of the power tower to feed a growing fleet of vehicles at different vectors all at the same time, is unknown.

Such a setup could terrace the way to the introduction of global beamed power from solar power satellite relays. This would allow unlimited free ranging. The problem here is that solar power satellites would have to be stationed in L4 or L5, the closest stable Moon-synchronous positions, some ten times further from the lunar surface than similar satellites in geosynchronous orbit are from Earth. Given the fall-off of power with the square of the distance, that's a hundredfold handicap to overcome. SPSs in L1 or L2 only twice as far out as Earth's geosynchronous orbit (only four times as handicapped) would require enormous resupplies of station-keeping fuel. And the problem of feeding many vehicles all at once with individual tight beams is the same.

It would seem then that there are just three really practical systems: (1) free-ranging larger nuclear powered craft; (2) vehicles burning powdered metal in oxygen limited to routes for which intermittent fuel resupply has been arranged; (3) fuel cell powered vehicles, also limited to serviced routes.

As has happened on Earth, there will be an evolving mix of vehicles of different types and those that work most efficiently and conveniently and inexpensively and reliably will become the standard. Again, as on Earth, there may be exceptions for local fleets where special support infrastructures might make sense, offering economies of opportunity.

✓ consumable reserves also limit the effective range of crewed vehicles. Air and water must be recycled and regenerated on board, probably without bioregenerative support except in larger craft. As to food, reliance must be on compact rations unless caches or depots have been arranged along the route. This limitation applies to otherwise unfettered nuclear craft as well.

The upshot is that travel over trackless areas, far from serviced routes, will be as non-casual as in similar situations on Earth, e.g. early Antarctic expeditions. Could one possibly have expected otherwise?

OVER THE ROAD LONG DISTANCE TRUCKING AND



OVER THE ROAD "RIGS" By Peter Kokh

Other than the cowboy, few occupations have been so romanticized as that of the over-the-road long-distance trucker. It is a calling definitely not for everyone, keeping one away from home and family for long periods of time. Of course, one end run around this drawback is the husband and wife trucking team which provides not only conjugal company but relief behind the wheel, even around-the-clock driving.

There is a romance about the road. It differs, of course, depending upon whether one plies a fixed route over and over on a week-in week-out schedule or ranges all over the map picking up cargoes of opportunity. In the one case the litany of truck stops and other diversions becomes routine, in the other it always keeps changing, though its poetry is the same. Inevitably one gets to know many others in the trade and it truly becomes a way of life – in the blood, as they say.

Truckers drive by day. They drive by headlight. They drive by radio, and by CB, and now cellular. They reckon by rote, by map, and now by Global Positioning Satellite systems. They acquire their handles, name their rigs, and their lore is mythologized in many a melancholy tune.

Many a business is at their service: motels, garages, restaurants, and complete truck stops; hookers on CB, radio stations, tractor customizing shops, custom apparel makers. Many a time myself on the highway day or night between country cottage and city four hours apart, I'd spot the Moon in the sky and wonder: "will it be the same up there?" Surely, not at first. But then the driving influences, the incentives, the needs – they'll be there unchanged. At first it will be lonely out vac, carrying a load the interminably long empty miles from Port Heinlein to Clarke City through grayscape after grayscape against black star-rich skies, and even lonelier by nightspan. But inevitably, eventually, it'll be "on the road again."

Distinctive features of Lunar Rigs

The Cab has to be/to do a lot of things. It must be pressurized, thermally well insulated, and provide for routine activities: sleeping, eating, hygiene, first aid, entertainment, communications, and more. Obviously we'll need more than a pair of seats and a bunk. In contrast to the current luxury super cabs of many modern long haul truck rigs, the cab of the lunar rig will have to be a camper-sized cocoon, a traveling truck stop, to use an oxymoron. It will be "self-contained", have walk around space, a galley area, a lounge area, maybe even a spare berth or two so that the rig operators can offer "tramp steamer" type accommodations to occasional passengers.

As to the cargo bed, this can be either pressurized or unpressurized, depending on the cargo (cf. the distinction between refrigerated and non-refrigerated trucks). If pressurized, it is likely to be separately so. The twists, turns, torsional stress and vibration that comes with movement over a surface that is not straight, flat, and level would tax any connection critically. There would be match-lock pressurized access to the hold only when the truck was parked, straight and level.

The cargo area may have an accessible solar flare storm cellar at the bottom so that any cargo carried could act as shielding. The cab-cocoon itself may have a storm cellar cubbyhole in the floor area, beneath water reserve tanks, fuel cells, and other heavy equipment.

Rig class ratings will tell the type of routes the rig is able to handle: unimproved but scouted routes, graded routes, routes with tended way stations or refueling stations, fully serviced routes with staffed service centers, etc. in declining order. This will work to prevent both operator and customer from undertaking foolish ventures.

Rigs will be largely self-servicing. They will be equipped to self-unload, with their own fork lift or crane. Cargo will be containerized as much as possible to allow easy, fast, low-risk, low-exposure loading and unloading. The rig would boast a strategically-stocked parts bin and tool crib.

Rigs will be designed and engineered for easy self repair. Pop-in/pop-out independently-suspended wheel/drive-motor modules might be the rule, each getting electric power from a central plant. Each rig might carry a spare module, with standardized replacements available at service centers. The rig would carry a piggyback open rover dingy for emergency travel and capable of transporting replacement parts like wheel/ drive modules.

Communications: both audio (radio) and video services will be possible either via L1 relay, or direct from Earth. A low orbit satellite network is not an easy answer. It would be prohibitively expensive to maintain because the perilune or low point of low lunar orbits decays too quickly towards inevitable surface impact. Entertainment and news casts especially packaged for lunar truckers, if originating in the main or other settlements via L1 relay, could conceivably be a favorite eavesdrop for their earth-bound counterparts.

Trucking in "deep" Lunar Farside, the 60° orange slice over the horizon not only from Earth but from relays in L4 and L5 as well, will require special communications arrangements. Perhaps a roadside cable with intermittent very-short range transmitters would allow one-way or two-way radio exchange say every few miles or every 15 minutes or so along the route.

Autopilots may be as popular and common on the Moon as cruise control on Earth. For there will be much less traffic; the slightest road jam will be fare for prime time newscasts less obstacles. The contingencies will be more routine. Autopilots may even be necessary for safety. For the very infrequency of situations requiring unprogrammable on-the-spot reflexes or reactions, along with the monotony of the scenery, unbroken by human-made structures and artifacts could tend to be very soporific.

Once there are a number of real settlements, there will be carriers who make the rounds, plying the circuit to pick up unordered specialty consignment goods in each community to make available in all the others. These "Gypsy Traders" will have pressurized holds and back up to settlement match locks in the "market" area. Arrivals will be well publicized. The holds may contain their own display space, or else goods to be merchandised may be prearranged on rollout display carts and cases. Items will run the gamut from arts and crafts furniture, furnishings, giftware, souvenirs, and apparel, to home-canned specialty food items not otherwise available.

Servicing smaller less self-sufficient outposts and stations will be traveling clinics equipped for routine surgical procedures and other treatments. An ophthalmologist/optician will be along. But these clinics will not be limited to medical practice. On the staff will likely be troubleshooting experts on agriculture and gardening, on recycling systems, and on biosphere maintenance. A dietitian will help plan strategies to meet deficiencies and other problems in the local diet.

A social worker and psychologist will be in demand, for lunar frontier life will have its share of stresses as well as rewards. An educational specialist will consult with outpost tutors. A writer/journalist will gather material for a round-robin news feature magazine and may need a sketch artist/photographer. A specialty barber/hair stylist may have plenty of customers for non-routine makeovers. Etc. [See MMM # 35 MAY '90 "Tea & Sugar" pp. 6-7 for discussion of a similar traveling clinic/general store making the rounds between asteroid outposts.]

There will be lots of interesting jobs and occupations on the space frontier. One of them, offering relief from cabin fever within the settlement will be overland truck driving. However, settlements may need to train a large surplus of qualified drivers. Because of the occupational hazard of accumulative radiation exposure, overland outgates driving will be only a part time occupation. Each driver will wear a bracelet that indicates accumulated rad exposure. Hired drivers and independent rig-operators alike may be scheduled to drive only a few months each year, alternating with another line of work, an ideal regular shot-in-the-arm morale booster. Or they may be scheduled to make but one round trip each lunar month. Such a situation will spur the rise of Coops of Independent Operators and co-owned rigs. At any rate, there should be no shortage of candidates.

MMM

[Designing “Amphibious” Spacecraft Cabins to be transformed into Lunar Surface Craft]

TOADMOBILE CONVERSIONS

By Peter Kokh

The problem is easily stated. Our first returning crews will need surface transport on the Moon immediately. Further, as the base expands and undertakes more activities, its surface transport requirements will grow and diversify rather quickly. Yet the day when such vehicles can be manufactured on site is far off. How do we get these craft to the lunar outpost site in the most economically sensible way? Consider that a lunar surface craft is still a spacecraft, in that it operates in near vacuum.

By Peter Kokh

Given that there is no atmosphere of consequence on the Moon, and precious little on Mars, the idea of using “hovercraft” or Ground Effects Vehicles to traverse off-road routes on either of those worlds is patently absurd. Or is it?

Yes, of course, we can’t just apply power to a downward ducted fan on a flexibly skirted vehicle and expect it to go anywhere. But it is not the ducted fan but skirt-contained over-pressure that is the essence of hovercraft. On both worlds, both because the gravity is less and the prevailing atmospheric pressure is lower than on Earth, the amount of trapped pressure needed to produce adequate lift will be much reduced. And conceivably at least, there may be a couple of ways to effect just such weight-compensating overpressure. All that is lacking is inventiveness, simulation, and testing.

Skimmers could provide the key to the globalization of the human presence on the Moon; on Mars as well

The market for a practical system could be rewarding in both locations. Skimmers could navigate rugged trackless boulder-strewn terrain at greater speed and comfort than any wheeled or walking vehicle. If practical and economically feasible to engineer and manufacture, the timely introduction of such skimmers could provide the key to the globalization of the human presence on the Moon and Mars, greatly reducing the need to grade/build extensive road networks, and helping preserve the lunar terrain in a more natural, wild state.

Terrestrial applications sufficiently profitable to drive “spin-up” predevelopment of analogous fanless craft on Earth in the near future are possible but admittedly not obvious to the writer. We welcome your suggestions in this regard.

Chemical propulsion for lunar skimmers

On the airless Moon, gas pressure retained under a ground-hugging flexible skirt can be produced by any rocket type thruster. Obviously we do not want either to be importing fuels for such purpose or to be using a combination whose vital working exhaust remains volatile. The ideal solution is an engine burning powdered lunar-mined metal in lunar processed oxygen. The exhaust, having done its lifting work, will settle back to the ground as an iron or aluminum oxide powder. That may visibly mark the path taken but hardly contaminate it any sense of the word. Such engines are yet to be engineered, even though the chemical possibility has long been known. One big potential problem lies in the weight of the fuels to be carried and/or the need for an infrastructure to provide for convenient en route refueling. While the range of the fully fueled Fe/O or Al/O lunar skimmer will be limited, one must bear in mind that since only a sixth the lifting power required for a similar craft on Earth will be needed on the Moon, a full tank will go for a surprisingly long way.

Dust-Pressure Skimmer Systems

Very large lunar skimmer craft more like barges than trucks or busses might be able to handle the lunar gravity reduced weight of a small submarine type nuclear propulsion plant. The power generated could feed a laser rake or sweep just to the rear of the front skirt, the effect being to stir up a lifting cloud of regolith dust, possibly enhanced by released fine-adsorbed gasses when traveling over virgin terrain. Would the lifting power so generated be sufficient for the job, marginal, or totally inadequate. We don’t know. Back of the envelope guesstimates from readers are most welcome.

If such regolith dust-cloud pressure is just marginally adequate given the weight of the nuke plant necessary, one solution may be to substitute beamed power from a solar power relay satellite. Beam driven skimmers could be a long time coming, waiting upon a space power infrastructure.

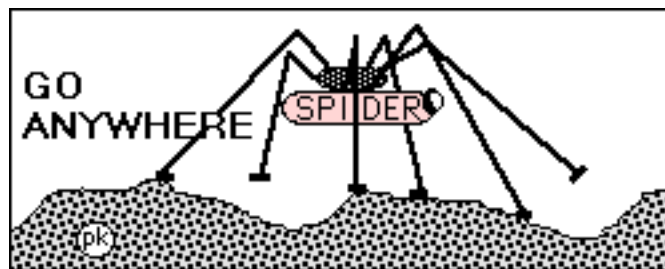
Skimmers could serve as personal transport, as trucks for priority shipments to isolated outposts, as go-most-anywhere platforms for selenologists (lunar geologists) on field trips, and for prospectors. They could also serve as rescue craft and ambulances.

Skimmers will be limited in what they can carry, at least relative to their own mass, size, and hovering thrust. But that constraint applies to most any vehicle, even on Earth.

Very large skimmers with broad beams could serve as “mare cruise ships”, leaving “wakes” but no tracks on the long frozen lava seas of the Moon, leisurely making the rounds between ports of call. They could import wholesale much of the romance, lore, and mystique of Earth’s high seas. Why not?

Mars skimmers: Different problem, different solution

On Mars, we do have an atmosphere, albeit a very tenuous one, and that offers us opportunities unavailable on the Moon. It means we can use hydrogen-filled bags for buoyancy, reducing the effective weight of the craft to be levitated off the terrain. It means we can compress the atmosphere itself to use as a lifting gas, though this will be harder to do than on Earth. It means the starring role of the skimmer on Mars is much less problematic than on the Moon.



GO ANYWHERE SPIDERS By Peter Kokh

One model from nature of a creature that can go just about anywhere is the spider. I have in mind particularly the mobility architecture of the “Daddy Longlegs”, in some places known as the “Harvestman”. Might not a lunar (or Martian) traveling conveyance of similar articulation and ability become an indispensable asset in opening up the more difficult reaches of both frontier worlds?

The Spider’s “body” would consist of two separable components: the “trunk” would contain the “hips” for the six legs and associated “musculature”, and the power, fuel, and motive plants. Underslung by a “dead man’s winch” would be the crew cabin. This position gives it shielding protection from the locomotive complex above as well as an unobstructed view of the terrain below. If power should fail, the crew cabin would automatically winch to the surface in a controlled descent. This deployment could be overridden, if there was any reason to remain aloft.

The scale of such a contraption could be rather large, in fact the larger the better within practical limits. The legs could be long enough to elevate the central pod complex some dozens of meters above terrain obstacles below. This height would also be of great advantage in scouting a pathway ahead.

The spider gait could bionically mimic that of real spiders and include a cautious grope as well as a trot of sorts when the going permits. All it takes is a computer program.

The feet, the knees and hips as well, could be sensor laden, feeding back first to neighboring and partner legs, then to the central nerve center. In this respect the model might rather be the loosely decentralized manner of the octopus. [See MMM # 45 MAY ‘91 ROBO ANTS” pp. 2–5] [included in MMM Classics #5]

Difficult Terrain Exploration

In the saturation bombardment craterland of the lunar “highlands”, it is in general possible to make one’s way by sticking to “intercrater” plains, ridges, and shoulders, avoiding steep inclines. But what if we want to visit the central peak of a debris- and boulder-strewn crater such as Tycho?

On the maria, the darkish solidified lava sheet “seas”, the going is generally easier, craters of size being fewer and further in between. But even the flatish maria are laden with obstacles such as sinuous rilles (relics of large collapsed near-surface lavatubes), lava sheet flow front escarpments, “reefs” of incompletely buried pre-flood “ghost” craters, and of course the ramparts of “coastal”

impact-upthrust mountain ranges. Such obstacles could make circuitous detours the norm rather than logical straight line routing – that is, if we are traveling by vehicle with limited ability to negotiate rough terrain.

On Mars there are similar relatively smooth and relatively rough areas, and similar obstacles. To be added in the mix are difficult landforms unknown on the Moon: crevasse-ridden layered polar ice caps, eroded slopes of the great shield volcanoes, dendritic tributary and distributary channels of ancient river and flood courses, chaotic labyrinths and canyon-lands. Many of the geologically and/or mineralogically (thus economically) more interesting spots on Mars lie smack in the midst of such harder to reach places.

Cache Emplacement

A go-anywhere spider vehicle could do preliminary geochemical assessments along its route, and emplace seismic monitor stations. Where such dust and rock samplings warrant, it could then put in place handy base camp supply caches for follow-up field expeditions and prospecting efforts.

Construction Crane Workhorse, Webspinner

A heavy-duty version of such a straddle-anything pick-its-way-anywhere vehicle could serve as a crane. As such it could do yeoman work in relatively urban settlement sites as well as in remote construction locations, becoming in this version the workhorse of lunar development, as well as scout.

Specialized versions could spin arrays of cables across craters to make radio telescope dishes and space-solar-power rectennas. They could also spin cables across rilles from shoulder to shoulder for bridges or to support habitat meta-structure roofs. Indeed, it is hard to see how we could long manage without them.



[Shelterless travel]

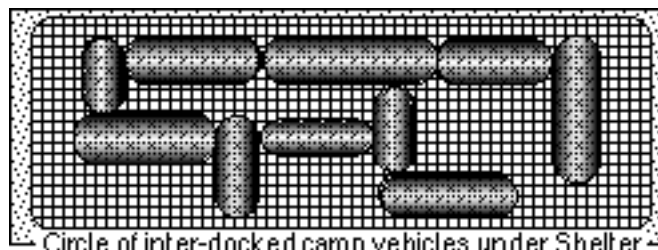


Roughing It for real

By Doug Armstrong and Peter Kokh, CCC

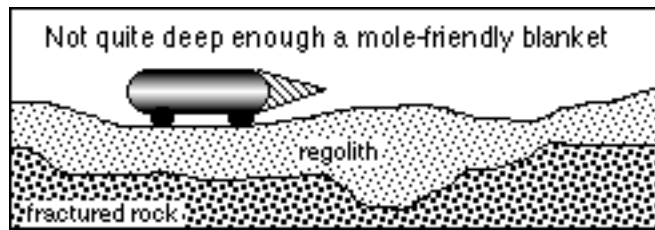
Off-road vehicles will not only ply trackless terrain but range far from convenient roadside flare sheds or wayplexes [see the articles on these topics in the October issue]. Short round trips can be ventured without provision for significant radiation shielding. But in times of Solar unrest especially, in Flare Season so to speak, off road vehicles must be prepared to “dig in” one way or the other.

This need is critical for remote construction site camps as well, whether engaged in building new outposts, mining operations, or road work. For the latter some sort of semi-permanent storm shelter would seem to be an immediate priority of setting up camp. Camp vehicles would normally park in an inter-docking array under the shelter. But here we are concerned rather with the situation for vehicles en route.

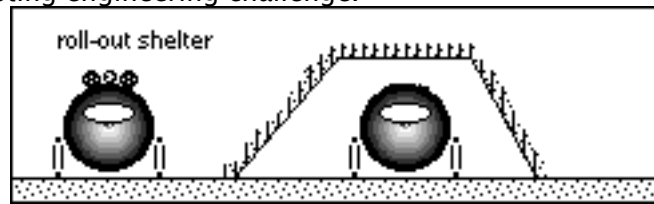


Circle of inter-docked camp vehicles under Shelter

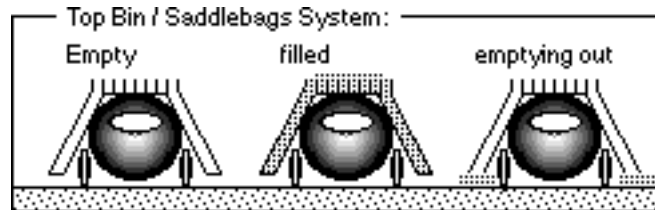
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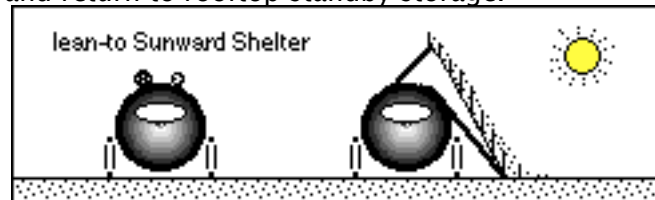
Another possibility is to carry along a collapsed, easily erectable space frame shelter and unrollable fiberglass canvas cover over which a scoop/conveyor system could blow regolith dust. Once deployed, such a shelter could be left in place permanently, its site marked on official maps for the convenience of others in the future. That leaves the vehicle, however, without protection if another storm should rise later at a point further along the route. Devising a way to “empty” the spaceframe/canvas shelter of its regolith overburden so that it can be packed up and stored on the vehicle rooftop or side for future use is an interesting engineering challenge.



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Actually, in latitudes some distance north or south of the lunar equator, the problem becomes easier. All that’s needed is a sloping shed facing Sunwards (recall that the Sun creeps slowly across the lunar sky at only 1/28th the pace we are used to on Earth). A Solar Windbreak will be easier both to deploy and fill and to empty and return to rooftop standby storage.



Even small open rover type buggies, should they venture much beyond the point of easy swift return will have to be equipped with some “KD” (easy erect, easy “knockdown”) system of flare storm protection. All vehicles of any kind, when parking at a site along the route for a few days would be advised to deploy their shelter system as a matter of prudence. In the meantime, even under calm Sun “weather”, the voyagers will be at reduced accumulative exposure to the weaker but incessant cosmic rays coming from all sky vectors.

At the heart of the matter is the functional analogy between the protective high pressure atmosphere of Earth and the regolith blanket which can serve as a condensed solidified atmosphere for the same protective purposes. MMM

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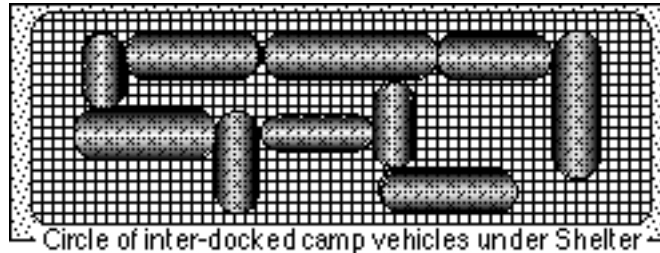
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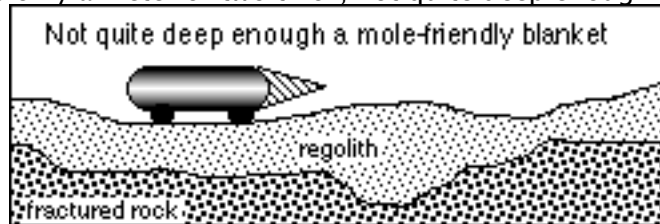
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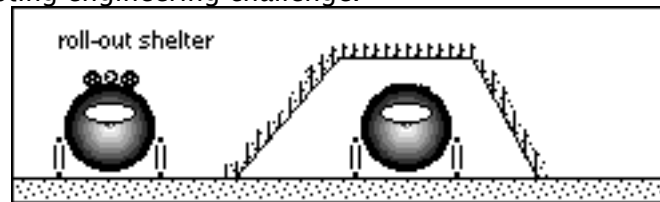
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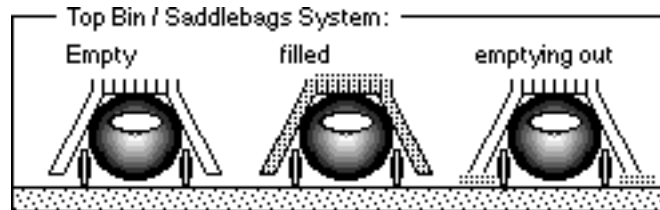
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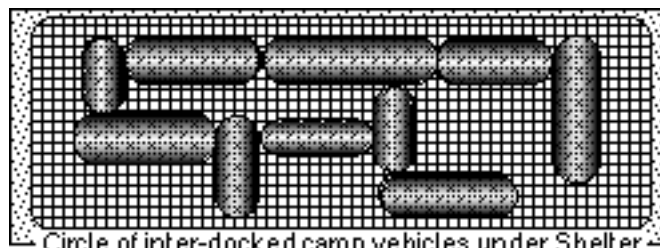
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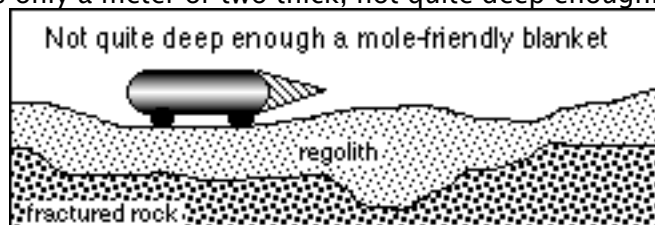
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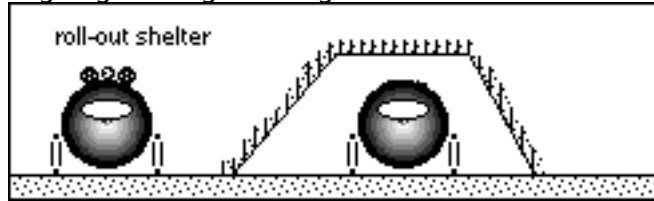
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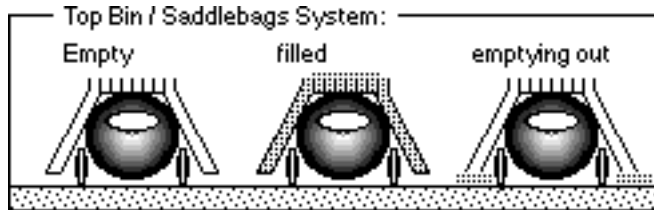


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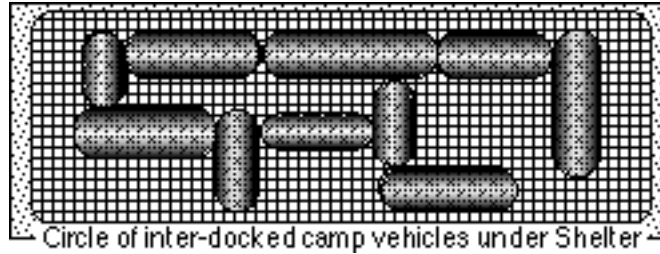
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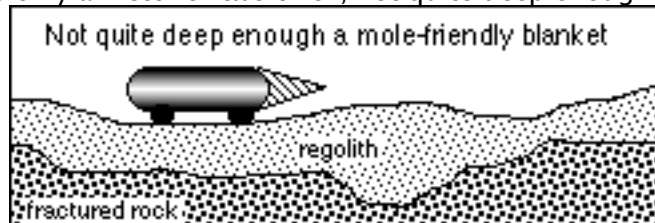
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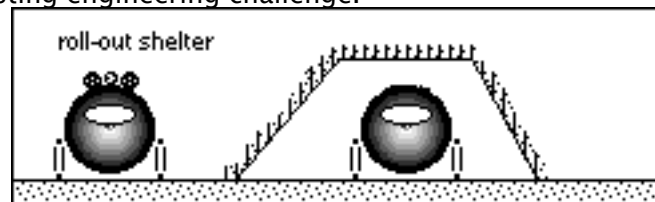
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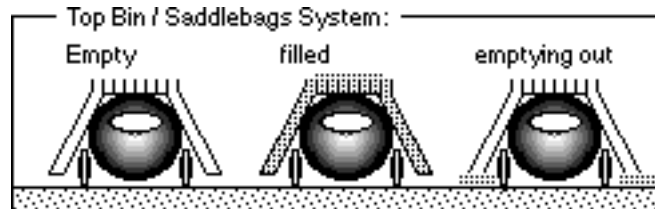
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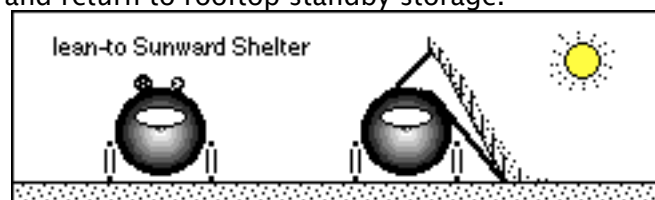
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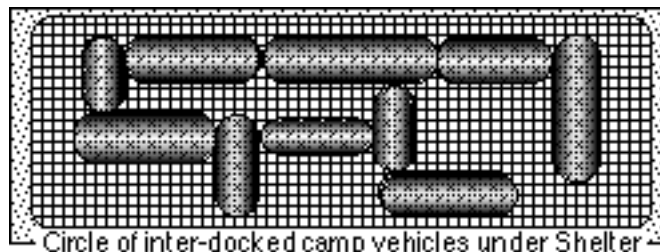
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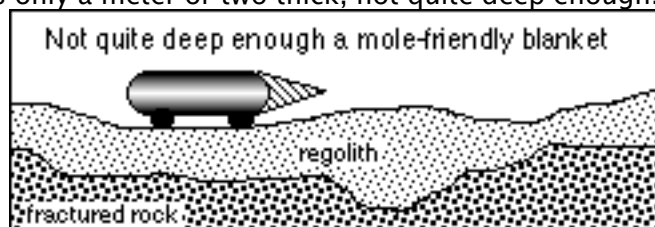
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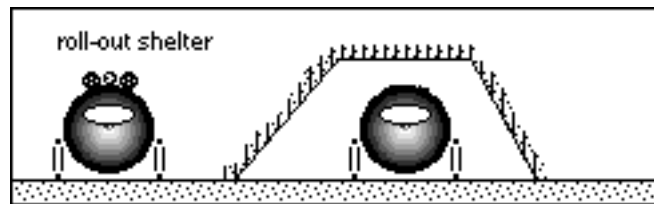


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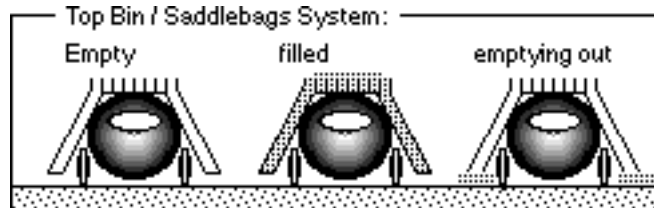
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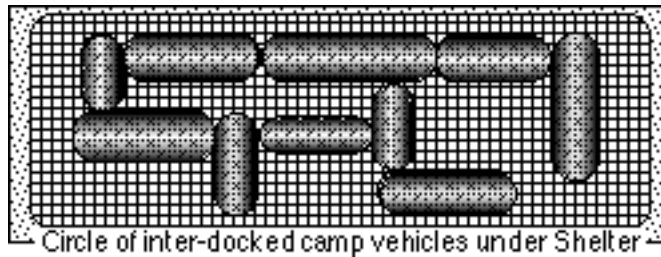
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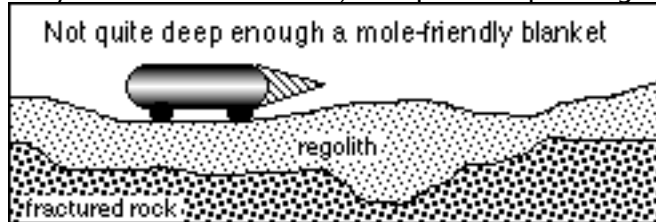
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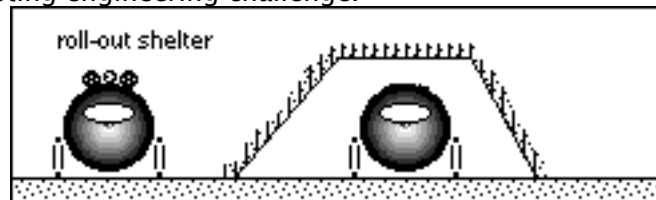
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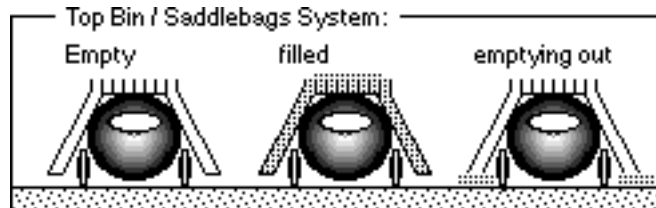
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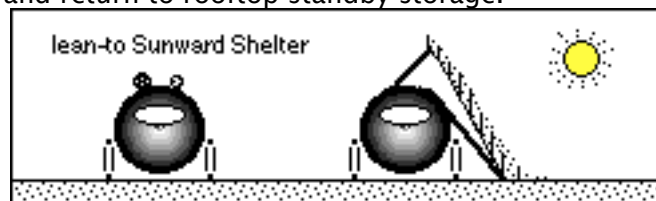
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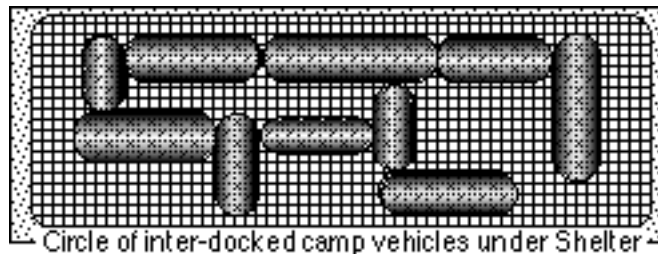
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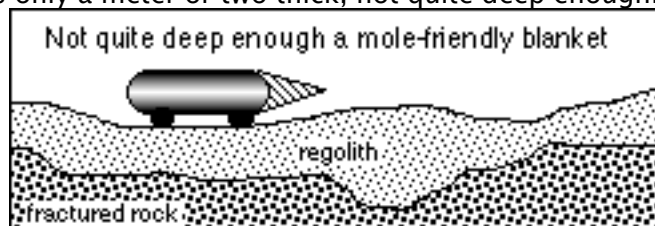
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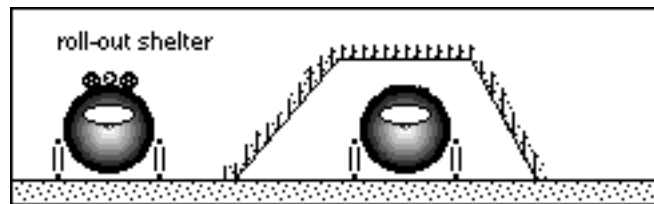
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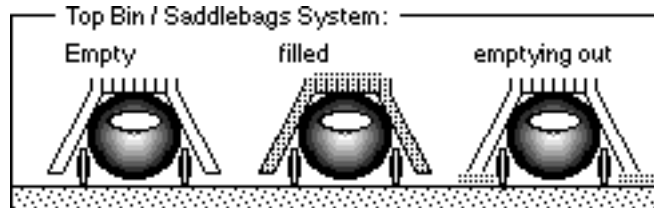
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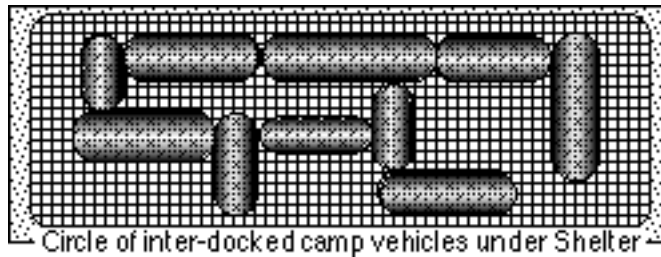
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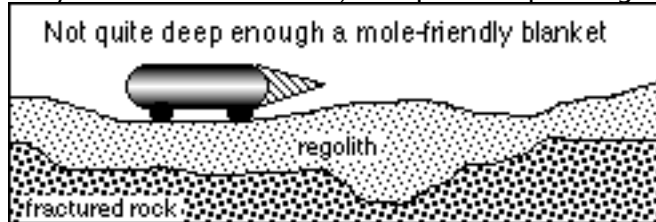
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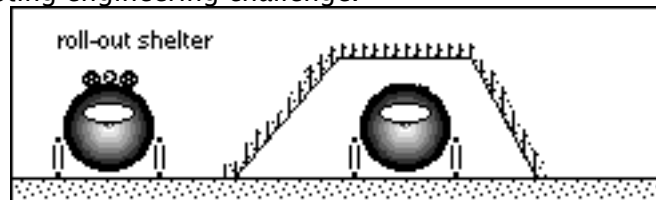
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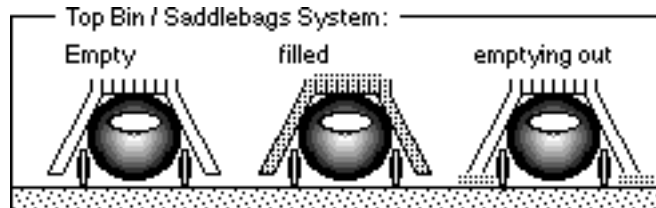
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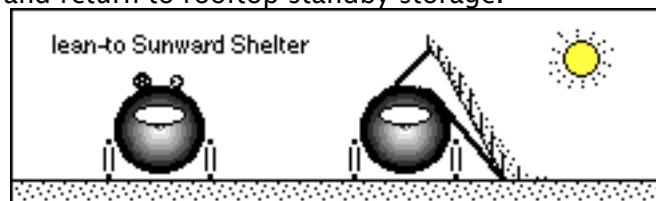
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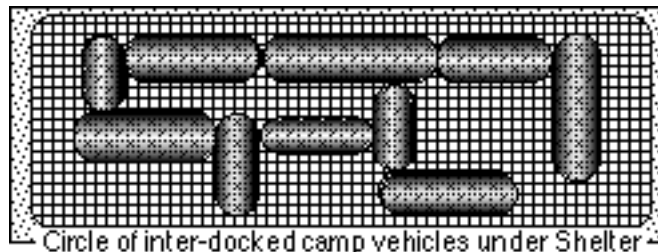
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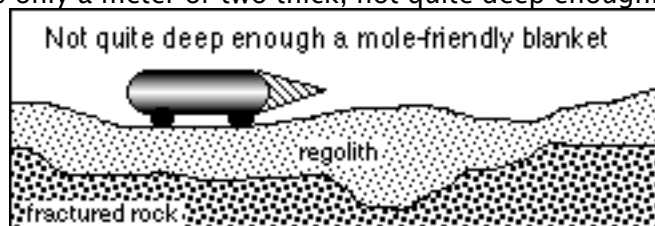
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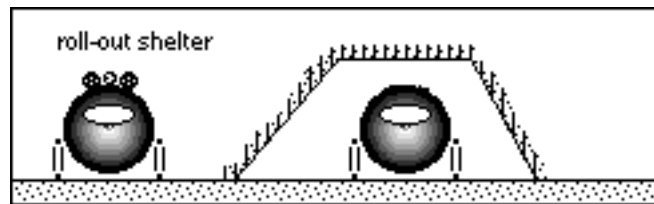
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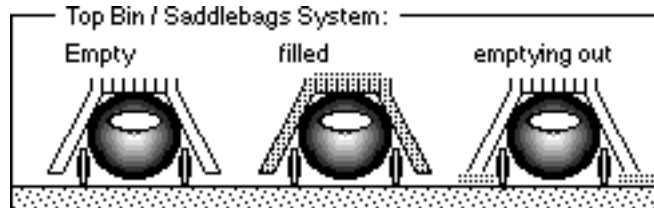
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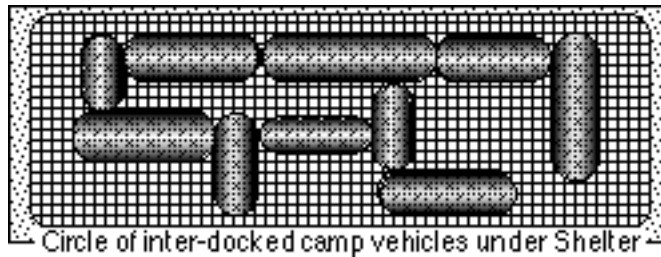
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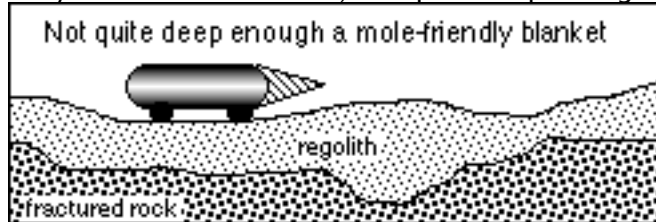
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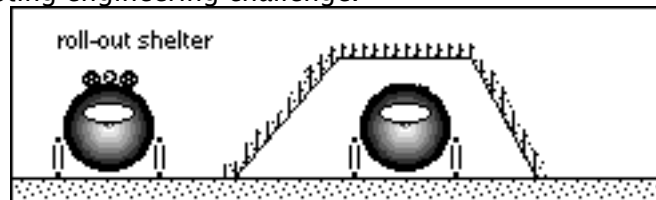
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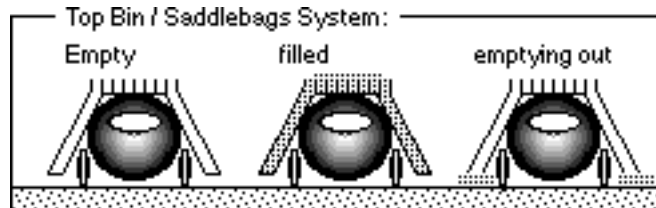
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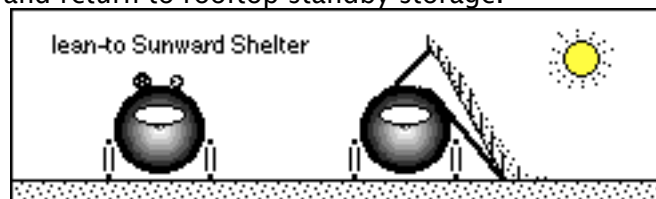
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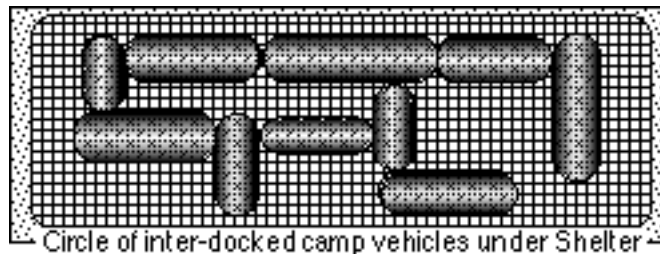
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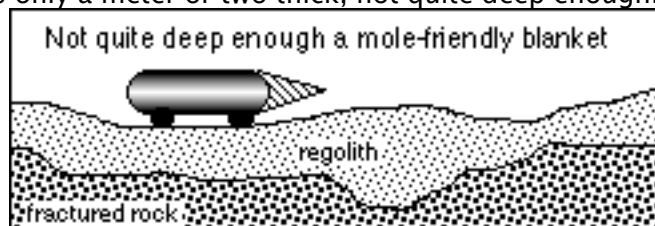
By Doug Armstrong and Peter Kokh, CCC

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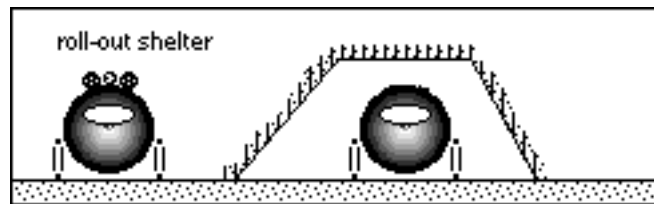
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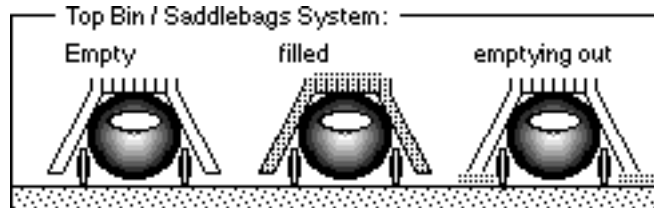
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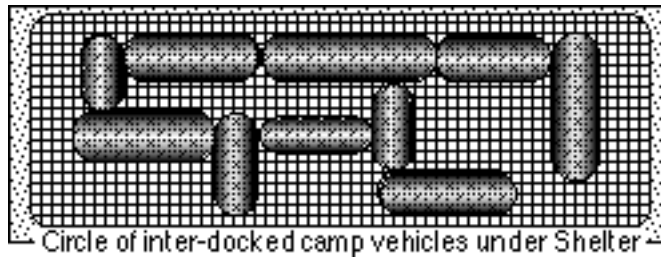
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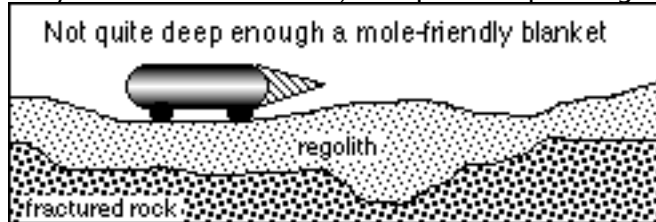
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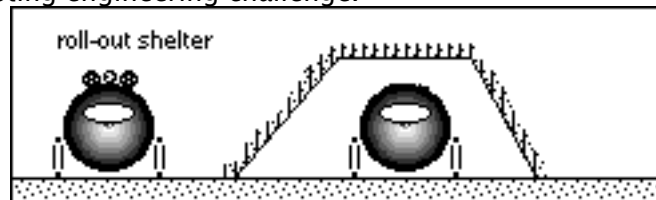
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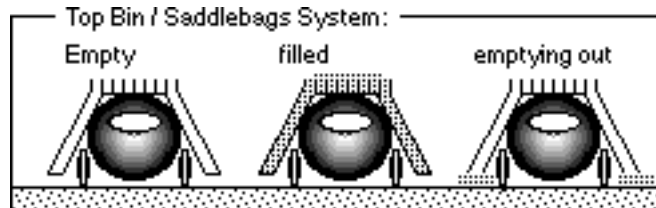
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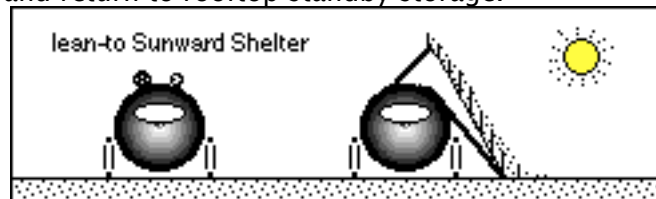
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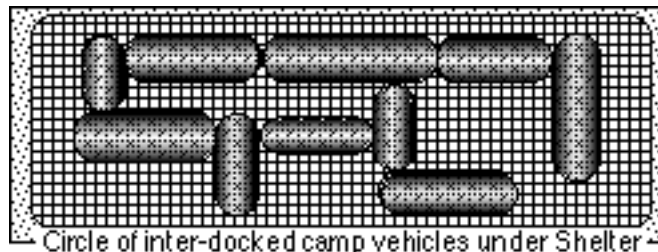
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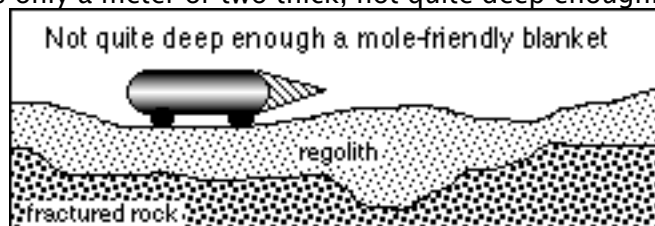
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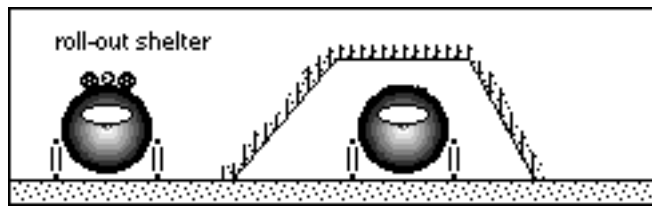
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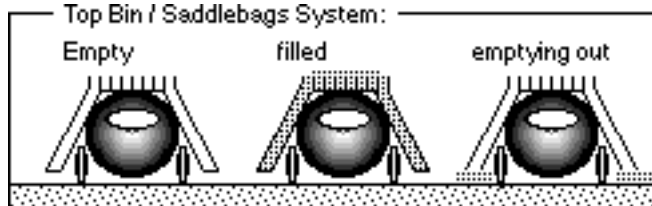
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MMM #82 – February 1995

[Series Continues]



RURAL LUNA Part III: The Beaten Path: possible early development of multiple lunar sites

By Peter Kokh

If we find water ice at either pole, that just makes certain that we will need “more than one” lunar outpost site and we’ll need them in the near term.

One technician's early read of then still incoming data from the Air Force/NASA Clementine orbital mapping probe, teasingly left open the possibility of fields of water ice (of unspecified expanse and depth) in a previously undetected deep lava-free impact basin at the south lunar pole. The eternal frigid cold (-230°C , -382°F) of the permashade there would tend to cold trap any comet impact derived volatiles successfully migrating to the area before the incessant Solar Wind buffeting the dayside could sweep them into space. Such deposits would slowly build up over geological time only if the accumulation rate is great enough to swamp the several loss mechanisms that must work tirelessly to erode them. That's a tall order, and we personally have expected a negative finding. All the same we have unwaveringly supported efforts to find out for sure. We cannot intelligently plan lunar development without knowing where we stand on the hydrogen problem.

Many others, however, optimistically anticipating a positive find of economically significant volumes of water-ice have declared that any such discover would settle the debate over outpost or settlement location. That's a curious conclusion! Is Los Angeles next to Nevada's Hoover Dam? Is Pittsburgh in Minnesota's Messabi Iron Range?

Water, or more specifically the hydrogen of which it makes up just 11% of the mass, is undeniably quite essential to lunar development of any kind, of any extent. We can use it up obscenely and squanderingly for rocket fuel if we are too lazy to explore more lunar-appropriate options (silane, SiH_4 , a hydrogen "extender"; powdered metals, etc.). But we certainly need it for food and fiber production and biosphere operation in general. Water and hydrogen both are hard to do without in "industry as we know it"; and finding cheap, accessible sources would make unnecessary taking up the difficult and unwelcome research challenge of finding anhydrous "xero-"processing and manufacturing methods.

Yet it is "not by water alone" that lunar pioneers shall live. If we are really going to use lunar resources, the tonnage of hydrogen and/or water needed in comparison to the tonnage of other elements will definitely be minor. For real industry, a "coastal" site at which both aluminum-rich highland and iron/titanium-rich mare [MAH ray] regolith soils are accessible would make the most sense. There are no mare areas near either pole!

Some of the other things we most want to do on the Moon ask for more equatorial sites as well: a deep farside radio astronomy facility; lunar solar power arrays on the E and W limbs. Obviously, if we find water ice at either pole, that just makes certain that we will need more than one lunar outpost site and we will need them in the near term.

Implications of South Polar Ice for "Rural Luna"

Our topic in this series is "Rural Luna". What impact would a confirmed find of economically recoverable deposits of water ice at either pole have on rural lunar development away from the main base, or bases? That comes down to a question about transportation. How do we get resources from where they are found, to where they will be used, i.e. to where they are in most demand?

Suppose we set up an ice-mining outpost at/near the lunar south pole. And, option A, we have another settlement supporting He-3 recovery in one of the nearside maria [MAH ria]. Or, option B, we have two settlements one somewhere on each limb (between nearside and farside, from which Earth is on the lunar horizon) to manufacture components for, and construct and operate vast lunar solar power arrays. Or, option C, we have a mining settlement along the nearside equator which sends lunar material via mass driver catapult into space for solar power satellite construction camps in the L4 and L5 lunar co-orbital fields. How do we get ice, water, or just hydrogen from the pole(s) to where its needed - at any/or all of the above?

We can do so by suborbital hopper, and make quick history of the lunar vacuum in the process. Or, much more interestingly, in a more environmentally friendly fashion, we can ship this polar elixir overland - by road and truck, and/or by pipeline. Routes leading from either pole to industrial sites elsewhere would engender "the beaten path".

Pipelines would need intermittent pumping stations and maintenance crews with intermittent shop/habitat facilities out of which to operate. Roads would need intermittent flare shelters and wayside sources of fuel, communication, and repair facilities. [Cf. "Waysides" and "Service Centers & Inns" MMM #79, Oct. '94, p. 15, republished in MMM Classics #8]. Some of these might in time evolve from visited, to tended, to permanently occupied settlements in their own right.

Since the first suggestion, ice/hydrogen transport by suborbital hoppers, is so unpregnant, so over and done with, let's assume common sense and the bottom line unite to beat overland paths between the pole and other sites. Does a look at the lunar globe tell us anything interesting?

A lot depends on where ice is found, at both poles, or only at the lower lying, colder south pole. As luck would have it, it is the north pole that is the handier to mare “coastal” sites. The north “shore” of Mare Frigoris (the “Sea of Cold”), lies within 27° or 500 miles of the North Pole. The southernmost “shore” of Mare Nubium (the “Sea of Clouds”), lies 60° or 1130 miles distant from the South Pole. From either of these coastal access points, the going gets easier to points anywhere in the connecting and clustering nearside maria.

The suspicion is that Helium-3 is more abundant in those mare areas that are ilmenite rich (ilmenite is an iron-titanium oxide ore). But such sites are to be found in many places. A South Pole only find would give the location advantage to helium-fertile sites in southern hemisphere maria like Humorum, Nubium, Nectaris, and Fecunditatis.

Another southern hemisphere mare, this one on the Deep Farside (over the radio horizon from L4 and L5 as well as from Earth), Mare Ingenii (the “Sea of Ingenuity”) should be on the short list for siting an extensive Farside Advanced Radio Astronomy Facility (FARAF) [cf. MMM #10 Nov. 1987 “FAR-SIDE” Part II, republished in MMM Classic #2.]. It may or may not be a good place to harvest Helium-3 as well. It would be more accessible to ice reserves at the South Pole than any other site on the short list (the flat mare-filled craters Tsiolkovsky and Aitken, and Mare Moscoviense, for example).

A mass-driver feeding construction in space (e.g. L5) would most efficiently be sited on the equator, some say about 30° E in Mare Tranquilitatis (the “Sea of Tranquility”), not far from the Apollo 11 touchdown site as happen-stance would have it. The path from the pole might be via Mare Nectaris (“Sea of Nectar”) and the Rheita Valley.

Dr. David Criswell, leading proponent of Lunar-based solar power arrays, proposes siting them in Mare Orientalis (the “Eastern Sea”) on the West Limb and in Mare Smythii, (“Smyth’s Sea”) on the East Limb. Now Mare Orientalis and associated Lakes (e.g. Lacus Verus) are the only choices in the West, and as luck has it, they are centered 20° S of the equator. Mare Smythii, on the other hand, is right on the equator and definitely not the only choice. Mare Australe (the “Southern Sea”) is also on the East Limb but only a bit more than half as far away from the South Pole. If either we find no water ice anywhere, or we find it at both poles, Criswell can have Mare Smythii. But a “South Pole only” find would make Mare Australe clearly the prime choice.

If we go the route of Lunar Solar Power Arrays on the limbs, there is also likely to be an overland route between the two. Nearside routing offers easier terrain, the bulk of it through mare areas. The impact of a South Pole Only find would be principally on the easternmost quarter of the traverse: from Orientalis through Tranquility, the logical “easy” route (Orientalis-Procellarum-Imbrium-Serenitatis-Tranquilitatis) would not be affected. Giving the nod to Australe over Smythii, however, could lead to an early pioneering of a ‘shortcut’ through the southern nearside highlands (Orientalis-Humorum-Nubium-Nectaris-S. Fecunditatis-Australe). Along either of these paths-in-the-beating, tertiary rural outposts and someday settlements are sure to rise.

Land Grant Spheres and Corridors

Confirmation of significant water-ice fields at either pole would create a dynamic economic polarity of Sunlands and Permashade, heat and cold, fueling the lunar development engine. Along the field lines of this polarity, “rural Luna” would arise first, thereafter spreading further afield, “off” the beaten “hydro” track.

A lunar development authority ought to legislate two types of special Development Zones. (1) Settlements should legally include **hinterlands** of some radius (to be determined, we would suggest at least 200 km or 120 mi) within which they have reserved mining rights to outlying resources of importance to their economies.

(2) Road Construction Companies and/or Pipeline Companies might also get real estate concessions in the form of **corridors** of a width to be determined – much as was granted to some of the U.S. western railroads. They in turn, would have the right to sell or lease lands within those corridor limits to mineral lode and tourist site developers and homesteaders. This would work to accelerate the establishment of Lunan civilization along these pathways.

Homework: surveying prospective routes

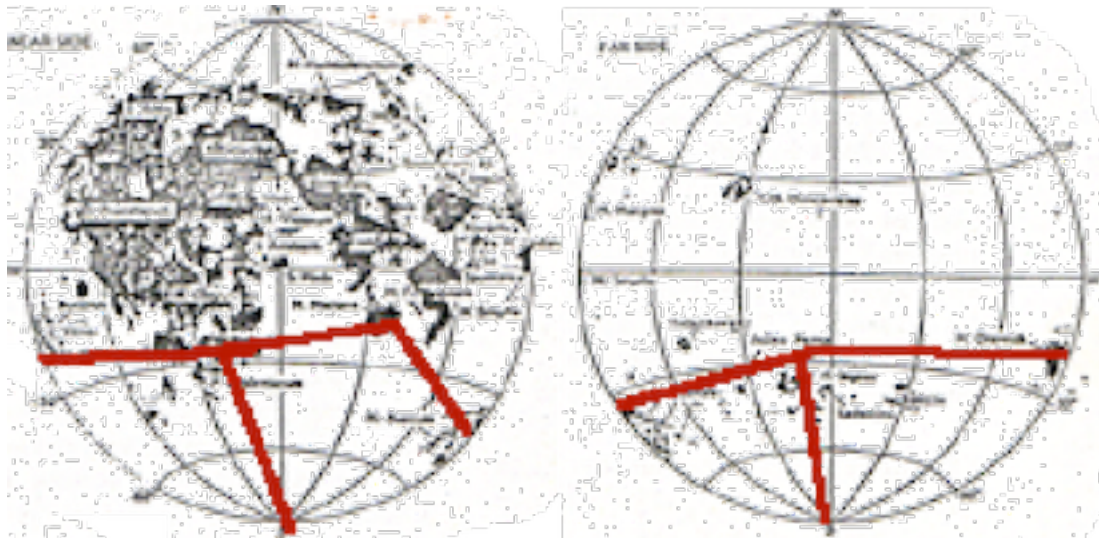
Thanks to Clementine and the vast amount of orbital mapping data it produced, we can start now to narrow down the logical routes northward from the South Pole to Mare Orientalis, Mare Nubium, Mare Nectaris, Mare Australe, and Mare Ingenii. At least the preliminary work in each instance could be done by anyone with access to Clementine data. Perhaps here is a chance to get your name in the Lunar History books. Other routes (East to West, etc.) also need surveying. Optional route locations need to be


rated in terms of construction difficulty and consequent expense. As on Earth, the easiest routes come first, engineering miracle shortcuts later.

Actual traffic routes are not always determined by the path of easiest construction, however. They can be distorted or attracted off the expected route by specific site-anchored assets. Especially promising ore deposits, if identified before hand, can influence the final choice of route. So might outstanding tourist attractions (e.g. The Straight Wall). While a number of non-topographical considerations may influence final corridor selection, a short list of promising routes can be put together with the information we already have.

The Beaten Path Nearside Routes

Beaten Path Farside Routes



[dark areas are lava sheet-filled mare basins] 

MMM #83 – March 1995



RURAL LUNA Part III: Off the Beaten Path

By Peter Kokh

What about Lunar communities outside the land-grant peripheries of the major settlements, and outside the land grant corridors of pipeline and inter-settlement road-construction companies? Will these unincorporated reaches remain empty? If not, how will any pockets of humanity therein survive and earn their keep? Our subtopic this month.

BACK READING: "Rural Luna" in MMM #15 MAY '88. [Republished in MMM Classics #2]



Tarn: [tahrn] (ME *terne* < Scand; cf. Icelandic *tjörn*: pond, pool)

(1) A small mountain lake or pool, such as in a closed glacier-scooped basin, often with no outlet and/or no specific inlet.

(2) By metaphor: a rural lunar outpost with no regular water or hydrogen resupply (not on a pipeline or regularly serviced truck route), protective of an initial water/hydrogen endowment.

By Peter Kokh

We indulge in introducing a new term here, because the pockets of humanity we foresee under this heading promise to be rather creatively unique as human cultural institutions go. Tarn type outposts will arise sooner or later primarily to meet a number of economic needs or scientific purposes.

But a significant secondary driver in their formation may be the unprecedented opportunity they will offer for small “intentional communities” and charismatic leaders desirous of developing their own forms of cultural, religious, economic, educational, philosophical, social, and familial expression — relatively free from interference, whether intended or not, thanks to their isolation and remoteness — “off the beaten track”.

Economic niches for tarns will be many. Unique mare, highland, volcanic, and central peak up-thrust mineral deposits not common elsewhere on the Moon surely rate at the top of this list. Tarns offering out of the way scenic sights and vacation experience treats for ambitious tourists in search of the extraordinary and uncommon are another likely category.

Some tarn hideaways could specialize in conducting spiritual retreats, short or long. Boarding school academy tarns could offer stricter discipline along with unexcelled education away from main settlement peer pressure distractions.

Monastery tarns could earn their keep raising agricultural specialties not otherwise available (chocolate? tea? silk? oranges?) A monastery might provide the resident everyday support staff for astronomers visiting a deep farside radio astronomy and S.E.T.I. installation.

Tarns could earn spare income by taking in individual students (both problem and gifted) from the urban settlements. Adult apprentices in Tarn specialty arts and crafts might also be welcomed. Others from the “city” could come on volunteer working vacations just for “tarn-raising” construction duty. For them, the change of scenery and life style, however temporary, could be a welcome shot in the arm.

It is likely that as the range of talents of tarn members increases and diversifies, so will their economic underpinnings. Each may also produce unique tarn-specific arts and crafts with which their names will become identified (much as do the various pueblo communities in our Southwest), all for export. Unique folk dances and costuming could appear. Tarn plants and animals and controlled climate could all be picked to offer commodities for trade to the larger settlements of items not available there. Add possibly tarn-specific architecture and interior design and furnishings. The clear upshot is that when you have visited and seen one, you will not have seen them all.

Older tarn youngsters might do a year or two of exchange education in another tarn. That would serve to cross-fertilize cultures and arts and crafts and, hopefully, lead to exogamy, and the avoidance of inbreeding.

On that topic, very small communities are specially prone to sexual imbalance. Unusual familial arrangements may be sanctioned in various tarns to redress this problem. [On this point, reread Heinlein’s “The Moon is a Harsh Mistress”.] Tarn children could be raised in common by all adults. Polygamy or polyandry might be encouraged. Superfamily ties will be strong.

Unique as each tarn community may be, they will have many problems and needs in common. This will surely give rise to some sort of mutual aid cooperative support association, with most business carried on over the electronic nets. The Lunar Frontier Republic may well have a special Office or Bureau of Tarn Affairs offering construction, educational, biospheric, agricultural, manufacturing, entrepreneurial, and health assistance. Hopefully such a government support office would not be a copy of our own patronizing BIA.

“Gypsy Traders” might ply the unimproved stretches between various tarns, picking up preserves and wares and artcrafts and other items for sale on consignment to other tarns and to the major settlements as well. They might offer “tramp steamer” type accommodations for tarnfolk and others seeking to get about.

Tarn life will be hard, character-forming. On Earth, those who want to be closer to nature head for the countryside. On the Moon it will be the larger settlements that will have the larger, lusher, more diversified, more soul-coddling bio-spheres. Yet tarn life will have its promised rewards and draw many. They will come direct from Earth, and second hand from the main settlements, too.

Our presence on the Moon will open with a single government or consortium-run outpost/settlement-to-be on an otherwise unoccupied alien world. But with the rise and spread of tarns, the Moon will become a second, adoptive home world for humanity. And the operative word here is “world”.
MMM

MMM #84 – April 1995



RURAL LUNA: This month we turn to the Economic Considerations that will affect the viability of rural outposts. We begin with some speculation as to “appropriate” physical construction methods that might make “tarn-raising” more feasible.

“TARN” ??? a Scandinavian word for a small, isolated mountain lake with no apparent inlet, but actually fed by rain or glacial melt-water;

We have adopted the word as a metaphor for the isolated “rural lunar” outpost that must religiously guard an initial water/hydrogen endowment, sources of loss make-up being costly.

Background Readings from past issues of MMM

[Republished in MMM Classics #1] – # 5 MAY ‘87 “LunARchitecture”

[Republished in MMM Classics #6] – # 50 NOV ‘91 pp. 6–8 “Hostel-Appropriate Architectures”

53 MAR ‘92 pp. 4–6 “Xity Plans” – # 54 APR ‘92 pp. 5–6 “Xity Plans, Pt. II”

55 MAY ‘92 p. 7 “Moon Roofs”; p. 8 “Shantytown”

[Republished in MMM Classics #8] – # 75 MAY ‘94 pp. 4–6 “Modular Architecture”



TARNTECTURE By Peter Kokh

Tarn Construction Materials and Methods

If there is to be a “rural Luna”, especially inexpensive methods for constructing suitable pressurized volume from local resources must be developed. Equipment involved ought to be mobile, so that it can, construction or expansion finished, be transported to the “next” site on the waiting list.

Construction methods can be many and various. First, modular building plans seem especially appropriate. But if it becomes feasible to erect a larger common pressure shell which can be subdivided at leisure with individual structures that need only provide privacy and partition, that may prove a popular choice as well.

Fast & easy installation, cheap in both materials and equipment lease or rental, spacious with room to grow into, low-maintenance and energy conserving — these are the desired features for tarn structure and tarn-raising. Mobile casting units for hex-flanged upper and lower dome hemispheres is one suggestion. Fiberglass-reinforced cast basalt might be a cheap enough option. Glax (fiberglass-glass matrix composites) would be more expensive. Iron in the form of an inexpensive and easy to formulate steel would be another option. A SLuGS (Seattle Lunar Group Studies) investigation showed that in the regolith excavated from a lunar habitat construction site, there are enough free unoxidized ‘un-ored’ iron fine particles from which to build the structure needed.

Leased or rented equipment should be mobile enough to be moved from site to site without prohibitive expense. This can be done “overland” on truck beds, or by suborbital hopper, depending upon where the next site is located, and how accessible it is.

Initially, of course, the dependence on city- (main “urban” manufacturing settlements) produced construction equipment and building products will be total. But that era should be short-lived. Quite possibly, a town once built and occupied, may, in order to expand at less cost, and at its own scheduling, develop modular building components of its own. This technology could then be exported to other town sites, either by way of the necessary capital equipment, leased technology, or simply by shipping manufactured building components ready to use. Either way, entrepreneurialism in improved town construction methods, equipment, and materials, should provide one or more towns with extra diversified income.

Lego like (iron) tins to be filled with regolith (reminiscent of the “world bottle” plan which called for the design and manufacture of beverage bottles so shaped that they could be used as structural bricks), vibra-packed sinter-blocks, sulfur(-impregnated regolith) block (100 times less total energy of manufacture than concrete block), are some lower technology products that suggest themselves. Mining towns could use tailings to make building material products. Town building “kits” are likely to include equipment, molds, and forms for use with local materials, plus suggested plans.

We expect that in most towns, the accent and emphasis will be on the communal commons, on dormitories rather than traditional residences, and on the work place. This tilt would seem to favor the megastructure approach, though all of the above features can be achieved by the modular method as well. The African Kraal or Coral and the Southwest Indian Pueblo communities come to mind: translated, that would indicate a common shield wall and large commons or community square. Community life will be the strong suite of rural lunar outposts. Within the common structure, peripheral to communal space, would be residential dorms and or family or super-family quarters, work places, agricultural/ horticultural areas, biosphere cycling equipment, and whatever else.

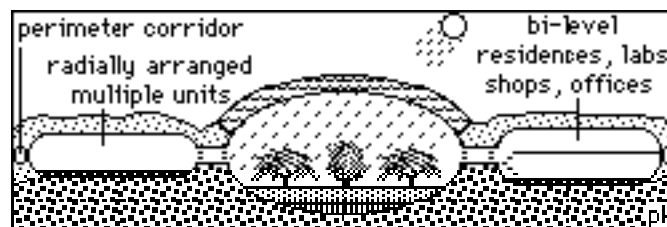
Towns will be individually distinctive

When you will have visited one town, will you have seen them all? Predictably not! Towns will differ from one another, first because their economic raison d'être will differ and be reflected both in the architecture and layout, and in the micro-culture of the place.

Second, **the very brashness of their attempt to survive and find a niche out in the lunar boondocks will assert itself by freely chosen arbitrary but highly visible architectural means.**

Examples?

1. Some, cherishing their isolation, may choose to blend into the moonscape unnoticed.
But others may want to catch the attention of passersby!
2. How about distinctive, eye-catching, even gaudy entrance gates?
3. How about colored-fiberglass “thatching” over their regolith mounds,
4. Or simply a layer of colored powder?
5. Or some telltale horizon-breaking structure, preferably with a legitimate function, visible for miles around?
6. Think of windmills, silos, and grain elevators in the American countryside.
7. A gleaming “hydroshield dome” putting the town water reserves to use as light-filtering shielding over a park-like commons in a suitably sized craterlet? [ILLUSTRATION BELOW]
- 8.



FIRMAMENT™ hydroshield domed–crater tarn commons with up to 24 ‘lithshielded cylindrical modules placed radially.

SOME PROBLEMS for hydroshield glass domes:

✓ **Keeping water cool enough thru dayspan, warm enough thru nightspan:** known infrared rejection coatings may be insufficient. An active dayspan heat rejection and nightspan heating system may be needed. The hydroshield might possibly be used as a heat sink for industrial activities during nightspan kicking in as temperature cools. This would reverse more conventional operations scheduling.

✓ **Vulnerability to failure thru micrometeorite puncture of outer and possibly inner glass:** a nightspan sphincter shutter system might be required. This shutter could be withdrawn over polar facing sun–shaded portion during dayspan. It should be closable within minutes given radar warning of incoming meteorites of dangerous size. This shutter could also close during scheduled 9 hour “nights” during dayspan if a staggered shift system is not in use. (And a small tight–knit community is likely to reject any staggered shift scheduling option.) These measures would both decrease the vulnerability to impact accidents and reduce the total heat rejection burden.

Diversity of Niche = Diversity in Appearance

Differences in appearance will flow not only from the choice of materials and construction methods. They will also flow from the tarn’s “vocation” and may be highly individual in character. There will be “family resemblances” also that advertise a group or class of tarns:

- **roadside service tarns** belonging to some chain or franchise operation
- **mining and processing tarns**
- tarns that offer **retreats for city–folk**
- tarns that conduct **special tourist excursions to scenic attractions** off the beaten path
- tarns that take in and **educate students in boarding school academy settings** free of urban distractions
- tarns that support **small science communities** e.g. at some giant lunar accelerator, or at a far–side radio astronomy/ S.E.T.I. installation, or at a major exploration site above a complex of lavatubes, etc. e
- tarns belonging to a **Lunan Farming Cooperative**
- tarns belonging to some **religious or social denomination or movement** seeking to flower more fully well apart from the mainstream of Lunan society.

Each category will by nature express its functional and psychological needs differently. And these differences will often be quite visible sometimes from outside approaches, but sometimes only in internal layout and decor. Form follows function. Transport magically to the tarn square and you should have a pretty good idea right away what sort of tarn you suddenly find yourself in. That spicy variety will make “Rural Luna” a “world” worth exploring. For those who cannot afford to visit them in person, there will be the fascinating articles and pictures in National Selenographic. M.M.M.

[and speaking of exploring ...]

Almost Forever



Relics of False Starts, of Boom & Bust

By Peter Kokh

When an outpost is built, won't it be "forever"? One would think that those proposing to set up an outpost would need a permit, the application for which required to give evidence of a sound business plan and adequate initial capital and other resources – lest the new commune become a ward of the state.

Oddly enough, the very first lunar outpost may not have to meet such a stringent test, especially if it is a government installation, its economic justification compromised in some committee. Thus it is the very mother of lunar outposts that is most likely to become a ruin, a place designed to "take steps" towards economic self-sufficiency "when and if funds allow." Hopefully, however, such a monstrosity will not follow on the footsteps of S.S. Freedom or S.S. Alpha.

Yet, given a first genuine lunar settlement, soundly grounded in economic activity, with openings emerging for peripheral encampments engaged in supporting roles, some of these smaller hamlets will indeed fail. They will fail despite careful review, despite land grant subsidies, SBIR type grants, and despite all other reasonable assistance.

The "market" may not pan out for the tarn's proposed product or service mix. That economic micro-niche may turn out to be temporary. A mining operation may prove to be too marginal. A crossroads location for a wayside service complex may never see the expected traffic. The crops planned for an agricultural tarn may not produce a regular profitable harvest. Tarns dependent on recruiting fresh pioneers may find their appeal too restrictive and never get the expected fresh blood.

Some tarns will be abandoned during construction, others soon after. Some will do well enough for years, perhaps even thrive, but then see their product and service mix become outdated, unwanted, behind-the-times, and be unable to adapt. A bad risk is taken in expansion. A new highway takes traffic elsewhere. Communal strife breaks out, defying reconciliation.

What will happen to abandoned tarns? On the Moon, they will hardly fall into "ruins" through mere neglect. There is no "weather" against which a "state of repair" need be maintained. There is no ecosystem that will reclaim the spot, to turn it back into forest or jungle. In Antarctica, where this is also true, and outposts and camps tend to be preserved, they still slowly get buried in accumulating snow pack. Not here.

The first risk is unauthorized plunder and cannibalization by others. Baring this, a tarn once built, or even partially built, remains an investment that can sooner or later find new owners, new purpose, new life. Others can someday take over, giving the place sufficient reinvestment, and new direction. In the meantime, abandoned sites would revert to ownership by the Frontier Government.

FRONTIER

MMM #85 – May 1995



RURAL LUNA By Peter Kokh

This month we continue our discussion of the various Economic Considerations that will affect the viability of rural outposts. These will vary greatly according to type of outpost.

To those joining us this issue, we are borrowing the Scandinavian term **tarn** which designates a small, isolated mountain lake with no apparent inlet, but actually fed by rain or glacial melt-water, as a

metaphor for the isolated “rural lunar” outpost that must religiously guard an initial water/hydrogen endowment, sources of loss make-up being costly.

Background Readings from past issues of MMM

[Republished in MMM Classics #1]

MMM #10 NOV '87 “FAR SIDE” Pt. II. The ideal site for front-line astronomy in the 21st Century”

[Republished in MMM Classics #4] – # 32 FEB '90 pp. 5–6 “Port NIMBY: Import/Export Sleeper”

[Republished in MMM Classics #8] – # 79 OCT '94 p. 15 “WAYSIDE”; “Service Center & Inn”

Way side Tarn

WAYSIDE TARNS By Peter Kokh

In the above mentioned articles from MMM # 79, we outlined how the need to provide for periodic roadside service could lead eventually to commercial inns catering first to truck traffic, then to more casual traffic, as that arises. As on Earth, Lunan entrepreneurs, as well as some coming directly from the home planet, will be eager to gamble on a “growing market” and build individual fields of dreams, in the hope that the business will come.

On Earth, there is only the banker to act as a reality check on questionable dreams – and we all know that bankers can be very lax in their examinations. On the Moon, where rural entrepreneurial success is likely to be somewhat more difficult to realize, it may be wise to put in place a licensing screen that will both act to screen out poorly based business plans and to challenge good planers to significantly improve their proposals. Not to do so will mean a waste of resources, public and private both, that might be more wisely used.

On the Moon, the chain and franchise operations will be especially attractive, if not to would be operators, then to their financial backers and underwriters. Proven pathways to success are a better gamble. Nonetheless, as here, individuals with a dream will manage to strike out on their own, and in the process introduce new service “products”.

As a “tarn”, any rural operation will have to be much more than a Ma & Pop endeavor if it is to succeed. There is a micro-biosphere to establish and maintain, not just a motel, restaurant, and gift shop to run. The minimum critical mass population of such rural lunar hamlets is likely to be more than a dozen – perhaps a lot more. The business plan will have to take the establishment and maintenance of the micro-biosphere into account.

If a restaurant is involved, operators will want to produce locally, at least some of the food offered. If a certain reputation for the special and the unique is one of the points of the business plan’s “Mission Statement”, that suggests that the tarn gardener be planting herbs, spices, vegetables, fruit, etc. that may not be common in lunar farms.

If a gift shop is involved, besides the usual tourist trap fare offered elsewhere, tarn residents with an arts & craft aptitude will be encouraged to devote some of their leisure time into producing gift and souvenir items unique to their tarn. These might be based on special agricultural byproducts, on local mineralogical resources, or simply on unique talents.

Special rest period services for road-weary travelers are another way for a roadside service tarn to distinguish itself and create a high profile public image. Such services need not be limited to the fleshpot variety. Other pampering services can include whirlpools, spas, steam rooms, saunas, exercise rooms, ball courts, dancing, grooming and makeup sessions and more. Tours of the surroundings or of unique aspects of the local tarn operation can be offered. Social events in which tarnfolk and traveler can mix may be welcome to both.

Vehicle service, repair, and maintenance will be the mainstay, of course. And, as on Earth, the three most important assets of any business plan, no matter how well thought out in its other aspects, will be “location, location, location.” A place of business will have to have quite a reputation to survive “off the beaten path”, even if the detour inconvenience is minor. Special bread and butter services like warehousing or operation of a special scenic concession may or may not provide the compensatory lure.

The best locations will be at crossroads and junctions and transportation nodes; places where goods can be off-loaded from one vehicle carrier to another and transshipped; and motor coach hubs

for transfer from one vehicle or carrier to another. But the busiest stops are not always the most pleasant, nor the most attractive. Some less advantaged sites are sure to thrive, as individual tarns work industriously to establish their place in the sun. Stopping en route will be as much risky fun on the Moon as on Earth.

FARM



FARM TARN By Peter Kokh

The incentives for a group to go off and farm by themselves can be many. The “climate” of the settlement biosphere may not be suitable for the growth of the crops species one wishes to plant. One may want a climate that is colder, or is subject to periodic frosts, or is more tropical, more moist, even more dry. While special climates can be effected in semi-separate parts of a main settlement, it may be simpler to have total separation. Quite likely, the practitioners of one type of farming will want themselves to experience the proper temperate, subtropical, tropical, or arid climate in their own habitat area common spaces, not only just in the farms. After all, climate is interwoven with culture as well as with agriculture. That is the total experience everywhere on Earth.

Perhaps also, it is zoning and land use tilts that do not favor the farming or horticultural methods one wishes to use. The settlement, for example, may have a decided tilt toward hydroponics, as it is more stingy in its pressurized space demands. This may not sit well with those determined to try a regolith-based analog of more traditional farming needs.

Plausibly there will be a need to quarantine some crop specialties from others, reducing risk of transmitted blights, pestilence, and disease. That works both ways, of course, and the settlement may put out the ‘not welcome’ sign at the same time as would-be rural farmers declare their own intent to sequester their chosen crops.

But there may well be non-germane motives at work. Many brought up in agricultural settings on Earth will cherish the rural experience and not want to be a “part” of the “Xity” experience, however large an agricultural operation the larger settlement needs to have as an integral part of its biospheric underpinning.

All this said, there remains (a) the need for any outpost to be an integral human community engaged in a full spectrum of self-supporting activities, of which farming will be a significant part within a range of limits; and (b) the fact that other activities seen as farming-compatible may have more specific location requirements and constraints than the major or minor farming operation. Thus, there is no reason not to combine farming with road service, or farming with science outpost support, or farming and mining operations. Unless, of course, the tarn founders seek isolation as an end in itself; and provided too, that such founders are successful in recruiting enough compatible pioneers to follow them.

Serendipitously or by dedicated search, some locations will be found in which the “soil” as raw, unevolved, and unweathered (by water and air) as it is, is so much more favorable to certain desirable crops as to warrant the establishment of a farming tarn operation even when the site lends itself well to none of the other suggested co-operations. Such out-of-the-way farm tarns will succeed only if the bottom line domestic/lunar and/or export/space demand for the crop in question is sufficiently large to underwrite all the bills. If despite this burden, a remote farm operation succeeds and thrives, it may become a magnet in its own right, attracting trade and traffic and other differently oriented outposts. The symbiosis and partnership of farm and village is age old. On the Moon too, they will thrive together.

As suggested, lunar farms need not justify their operations in the lunar market alone. Almost any food grown on the Moon with lunar oxygen and many lunar-sourced macro- and micro-nutrients will be cheaper to purchase in any space place, even Earth-hugging low orbit, than food raised on the Earth’s surface, no matter how much more cheaply and efficiently, but brought up the steep gravity well at high fuel expenditures. Only special delicacies or treats available from Earth alone will make it onto space pantry shelves and into space eatery menus.

Special export and domestic crops overlooked in tightly planned and eco-balanced settlement biosphere farming operations could include Coffee, Tea, Spices & Herbs; fruit and vegetable specialties; supplementary meat producing animals and animal products; additional fiber producing plants; pharmaceutical feedstock plants; dyestuff plants; and more.

Almost any farm operation will earn income from a visitors' greengrocery as from a shop selling recyclable wares made from agricultural byproducts. Almost any farm too could offer an in-farm picnic and R&R spot for travelers.

Farm tarns will not only add to the total biospheric mass in place on the Moon, they may become a key player in the Moon's drive for economic autonomy and self-sufficiency. The "civilizing partnership" will continue. MMMM

Mining Tarns

MINING TARNs By Peter Kokh

The Moon is much more "homogeneous" mineralogically speaking, than is the Earth, not having undergone the eons of hydrotectonic geological processing that resulted in most "ore" veins on the human home planet. The percentages of the big seven (oxygen, silicon, aluminum, iron, magnesium, calcium, and titanium) vary within general ranges that would allow an industrial settlement to locate in most any "coastal" location from which both highland and mare type soils can be easily accessed. Titanium is the major exception to this rule.

Nonetheless, specialized mining operations that exploit relatively small abundance differences are sure to arise once the market for their mono-products are sufficiently strong. Entrepreneurial exploitation of unique mineral resource endowments, however, will not be limited to the big seven. As the industrial economy on the Moon slowly diversifies, the need to produce elements present in lesser abundances will give rise to scattered operations in many places.

In general terms, some of these special sites can be predicted. Foremost will be polar permafrost water-ice fields if indeed such comet-derived deposits exist. Then there may quite atypical Sudbury type asteroid-impact derived endowments of nickel and copper and other useful metals. They await discovery and are conjectural at present.

Crater central peaks are likely to be composed of mantle upthrust material that may be enriched in aluminum over common highland abundances. And here and there are fields of the so-called KREEP deposits ("potassium, rare earth elements, and phosphorus") such as those from the splashout of the Mare Imbrium basin forming event.

Apollo Orbiting Command Modules 15 through 17 were equipped with gamma ray spectrometers which scanned the equatorial regions. Among other things, they found scattered traces of Thorium which might indicate the presence of lead and uranium as well. There will here and there be found other atypical concentrations of economic value, including possible gas trap reservoirs of minor or major importance.

Locally owned mining "tarns", as distinct from non-family based "company" operations, will want to preferentially ship value-added processed products and manufactures. So they should become critical nuclei of industrial villages or settlements. Of course, they will need to be into farming too! And unique mineral-based arts and crafts are a certainty.

Mining tarns will be part of the rural triad that turns the Moon from "a one-town rock" into a "world". MMMM

The Lunar Jumping Jeep

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How will the early lunar settlers get around, say from Armstrong Base, to Kennedytown, to Water Mine #1? The only surface lunar transportation used thus far by the human species is walking or wheeled cars. The lunar rovers used had a very slow speed and a very limited range. Further, they were limited to reasonable flat terrain. Hence they are not suitable for traveling between sites a few hundred miles apart.

Much later in the era of lunar settlement, when we are talking about routine travel between cities, we can either build highways or railroads to facilitate high speed travel. But in the pioneer days, we need an intermediate solution, a "lunar jeep."

We need an off road vehicle that is suitable for traversing the very rugged lunar surface at a reasonable speed. The low gravity and the vacuum conditions suggest an interesting possibility, a jumping vehicle that leaps from place to place across the terrain. This will enable it to go over large boulders in its path, climb into / out of giant craters, or bound over deep crevices. Further, it should be quite economical on energy consumption, permitting substantial travel with one refueling.

This author proposed such a vehicle in the early 1960's, believing the idea to be original, for a tiny lunar rover to be carried to the moon by Surveyor. As is often the case, it was later learned that the same concept had been proposed previously; in this case by none other than Hermann Oberth. He wrote a book in 1959 called "The Moon Car," which described a much larger manned vehicle that could either roll along, or jump over obstacles. The principles described in that book are sound, but the advent of microelectronics has opened up control possibilities not foreseen by Oberth, making the concept even more practical.

For a manned vehicle, the limit to the jumper's capabilities is limited by the amount of jump acceleration the crew can withstand. Assuming that a human crew is willing to withstand repeated jumps at three gee acceleration, then a vehicle with telescoping legs that can extend 18 meters (59 feet) with that force, then we have a vehicle that can jump four tenths of a mile at a time. When leaping for maximum distance per jump, such a machine will spend about thirty seconds on each such jump, and will soar over five hundred feet into the lunar sky at the peak of each leap. Tall buildings at a single bound, indeed!

Moreover, the energy consumption of this machine will be small, assuming only that the lunar soil will remain compacted after it has been jumped upon a few times. The energy used to make one jump can be recovered by the tele-scoping legs upon landing. Then the only losses are the friction in the leg extension and retraction. (There is, of course, no air drag.) If these losses are only 1% of the energy needed for each jump, then an ordinary automobile battery (of 200 ampere-hour capacity) would store enough energy to take a one metric tonne vehicle a few hundred miles. And of course, aerospace batteries are even lighter than car batteries.

Assuming that a pioneer has already scouted the terrain, so that you have a "digital map" to exactly plan each jump in advance, then at the rate of a jump every 30 seconds, you can travel at 48 miles an hour. If the path has not been surveyed ahead, then you will need to go more slowly, so you can examine each landing site as you approach it, and manually determine the jumping commands to lead you to a safe landing.

There may be a business opportunity here for a daring entrepreneur. The same principles will work on Earth, although each jump will be six times shorter and lower. What a carnival ride such a machine might make! You will have a solid patent position when the time comes that we need jumping machines for the serious business of lunar settlement.

JC

MMM #86 – June 1995

[Series Conclusion]



RURAL LUNA

To those joining us this issue, we are borrowing the Scandinavian term **tarn** which designates a small, isolated mountain lake with no apparent inlet, but actually fed by rain or glacial melt-water, as a metaphor for the isolated “rural lunar” outpost that must religiously guard an initial water/hydrogen endowment, sources of loss make-up being costly.

Science Tarns

Selenology/Prospecting Field Camps – Lavatube Exploration Camps – Physics Labs & Accelerators – Optical & Radio Astronomy Observatories – Experimental Agriculture – Biochemistry Labs – Toxic Waste Storage – Nuclear Waste Storage & Energy Recovery – Experimental Genetic Engineering – Disease Control & Biological Agent Quarantine – Historical Preservation & Archiving.

There are several kinds of scientific activities that we will want to undertake on the Moon, and many of them can be done better in isolation from (relatively speaking) major population centers. Others of their very nature will demand an isolated “rural” location. There is plenty of room for physical isolation on the Moon, and the virtual biological quarantine enforced by the Moon’s lack of an atmosphere or hydrosphere is an invaluable asset for experiments that would otherwise involve risks with serious downside consequences.

Much field work remains if we are to understand the Moon well. Selenological Field Stations may be temporary and movable. A camp at an entrance to a multi-tier maze of intact lavatubes on various levels might be in use indefinitely. Deep shafts will core mare layers and sample mantle upthrust material in crater central peaks. We’ll search for Sudbury-like strikes of strategic ores of nickel, copper, platinum, and the like. Some of such prospecting field camps will evolve into permanent resource developing settlements playing a major role in the diversifying interdependent lunar economy.

Extensive areas of flat unencumbered real estate will attract gargantuan accelerator projects dwarfing the aborted SCSC. For maximum shielded cosmological labs monitoring neutrinos etc. the cooler lunar interior will permit much deeper shafts before residual crustal heat becomes a problem.

Optical Observatories and truly giant interferometers can be sited most anywhere. Those at higher northern and southern latitudes will be able to pursue unbroken dedicated around-the-clock study of major circum polar objects, like the Magellanic Clouds. Radio Astronomy installations will need to be located in Deep Farside (Mare Ingenii’s large flat-floored Thomson crater seems most ideal). Those installations that require considerable support may work toward localizing such support giving rise to small settlements engaged in food production, specialized fabrication shops, and maybe even sporting small universities or institutes and conference centers.

In Rural Luna, experimental farms will operate with-out fear of blight or pest or pathogen exchange with settlement biosphere food production areas. Larger scale trial biospheres could evolve into Lunar National Parks, becoming major tourist attractions for Lunans, if not for spoiled terrestrial visitors. Such forested and meadowed rille-bottom oases could support wildlife observation, camping, hiking, boating, riding, fishing, even simulated sport hunting.


This same hard quarantine will be ideal for otherwise potentially dangerous genetic engineering experiments, that nonetheless will inevitably shed light on who and what we are. Perhaps the same isolation may be advisable for riskier aspects of brave new world nanotechnology development.

Nuclear waste storage would benefit from the lack of ambient atmosphere and hydrosphere. In rural Luna, we can experiment with harvesting both energy and useful materials from such wastes. The same goes for biological and chemical toxin storage and experimental processing labs.

[See MMM #32 FEB ‘90 pp. 5-6, “Port Nimby: Export-Import Sleeper” – Republished in MMM Classics #4]

Another less obvious but in the end incomparably more important kind of scientific activity ideal for Rural Luna is the establishment of a disaster proof repository or Grand Archives of all humanity and human history, and of Gaia: life on Earth. Despite our best efforts, we are continually losing irreplaceable human treasures and natural history collections to war, criminally misguided fundamentalist purges (Library of Alexandria, the Mayan Codex), floods (the Arno in Florence), fire, hurricanes, tornados, acid rain and just plain rot.

Lavatubes on the Moon have already survived billions of years intact. They offer cold supervoluminous “lee” vacuum unexposed to the cosmic elements. Could anything be more ideal? Here we could

build the ultimate repository safe from mischief as well as accident; quarantined from biological attack; safe from the glaciers that will sooner or later wipe clean the slates of Canada, Scandinavia, much of Northern Russia and the Northern U.S.; safe from eventual demolition by geological and tectonic processes; relatively protected even from chance killer asteroid impacts. Such a vault should long outlive our species and be available for the inspection of visitors from other surviving worlds millions, even billions of years hence. If it's ultimately immortality that we seek in space, such a lunar lavatube archival repository ought to be rallying priority number one. 



RECLUSE TARNs By Peter Kokh

In addition to those activities which need or might benefit from a certain amount of isolation and quarantine, there are likely to be rural population pockets which have sought and continue to rigorously cherish isolation for purely social reasons. They pursue some “way of life” dream or vision.

These are the “Intentional Communities” driven by some religious (not always fundamentalist nor cultist), philosophical, economical, or purely sociological need for “purity”. Founders and followers seek relief from interference and distraction, from the need to compete with more tempting and easier alternatives in undisciplined pluralist mainstream societies.

We should not assume all such efforts are misguided, though history has shown that most of them end up in failure, and not always for reason of breached isolation. There do remain social and economic and political and other institutional experiments arguably worth pursuing but which cannot germinate or bloom, much less hope for harvest, in the midst of free form anything-goes society.

Many in the “movement”, especially fans of Space Colonies (Settlements), admit to having been attracted to the space frontier precisely for the opportunities of intentional community so enabled. Rural Luna should beckon them.

Monasteries are undeniably out of fashion, if only because both celibacy and deliberate poverty are out of vogue. But these days in the age of AIDS, contempt for celibacy is noticeably on the decline. In this new climate, the reappearance of communities of monks choosing a life of quiet isolation is possible. Like those who have blazed this trail before, they would devote their sublimated sexual energies to routine and other tedious labors of love seeking some form of communion with the transcendental. Such a life offers few compensations of common appeal. Yet for monasticism to thrive anew, there is no need to appeal to the many – only to a sustainable few.

Some activities in Rural Luna would seem ideal for future practitioners of the monastic way of life. Operation of a Grand Archives of all Humanity and Gaia; or running experimental farms (and vineyards); or operating a Port Nimby (“Not In My Back Yard”) type facility; or supporting a Deep Farside S.E.T.I. installation listening for whispers from possibly wiser fellow soul mates in the larger Cosmos.

Deep Farside locations with skies oriented toward the Universe-at-large and averted from Earth and its electronic relay ‘noise’ will be especially conducive to this life choice. Here lie vast expanses of endless peace, quiet, freedom from distraction.

Might the time might not be ripe for a precursor monastic operation in Antarctica? Here is a less “threatening” way to establish pockets of humanity on that virgin continent-on-a-pedestal. A monastery could explore environmentally benign, low-impact forms of site-rooted self-reliant economic activity. In addition to Antarctic-appropriate agriculture and resource harvesting, monks could earn credit for needed import resupplies by tedious tasks in danger of being abandoned in budget crunches (e.g. Planetary Science Data Reduction.)

Or they might offer alternative resting spots for those seeking an option to burial or cremation. In the cold dry air of Antarctica, open air burial under the stars is possible. Such a “desiccatorium” could

provide glass canopies to greatly retard blackening from ultraviolet and cosmic rays, with durable side netting to thwart the sky-patrolling carrion-feeding skuas.

We do not stray. There are many less attractive backwaters on the space frontier that may go wholly undeveloped except for special societies like monasteries. [Or prisons! See MMM # 35 MAY '90 p 3. "Ports of Pardon" - Republished in MMM Classics #4] The Moon is big enough for options like these.

MMM



Annexing 2/3 of Farside to Nearside: RELAYSIDE By Peter Kokh

We all learned when we were tikes that the Moon keeps one and the same face forever turned toward Earth, that there is another hidden side forever hidden from view - until the Space Age, of course. It is not a 50-50 split. The Moon's orbit around Earth is eccentric, swinging between a monthly close approach about 220,000 miles out and a monthly far point about 260,000 miles out. As it does so, its axial rotation which is locked to its orbital period, first lags behind its orbital progress as it speeds up approaching the near point (perilune) and then runs ahead as it slows down approaching the far point. The result is an apparent wobble or libration that allows us alternately to peak 6° or 7° around either side. So in fact, only 41% of the Moon is always visible from Earth, and 59% is at some times observable. The remaining 41% is always averted. The 18% "limbland" areas might be dubbed The Peek-a-boos.

This apportionment will change effectively if we put relay satellites in the gravitationally stable Earth-Moon no man's lands of the forward (L4) and/or following (L5) Lagrange points co-orbiting the Earth in formation with the Moon 60° ahead and 60° behind the Moon, respectively. Such relays will allow us to "see" or communicate with the pair of 60° orange slices of Farside flanking the visual limbs, leaving the central 60° still out of touch. The same orbital libration will work to trim the always-out-of-touch "Deep Farside" to about 45°, a mere but all-important 1/8th of the Moon's surface.

While this area could be served by another relay in the L2 Lagrange position some 40,000 miles behind the Moon, the considerable, unduplicatable, irreplaceable, and invaluable radio silence of this Deep Farside area will make that choice unthinkable. We need that sheer undisturbed radio silence both for advanced radio astronomy installations and for S.E.T.I. observatories [radio Search for ExtraTerrestrial Intelligence].

Rural Luna outposts and towns in "Relayside" will be no more isolated from Earth than Nearside communities. As to the absence of Earth in their visual sky, it is only fair to point out that Earth is also somewhat "out-of-sight-out-of-mind" in central nearside where it is very high above the horizon. (Thus the nickname of The Crooknecks for central Nearside.)

Outposts in Deep Farside, however, can only hope to remain in regular touch by cable to antennae in Relayside. The expense of laying cable (or a chain of laser-repeating towers?) will work to confine such outposts to narrow corridors leading to installations that by nature can only be in Deep Farside (the radio astronomy and S.E.T.I. installations just mentioned).

Relayside and Deep Farside pockets of humanity will have one psychologically binding glory in common, however. The absence of Earth above the horizon gives this area the most spectacularly star-spangled, Milky Way-blazen nightspan skies in the inner Solar System. **MMM**



THE ROLE OF RURAL LUNA IN THE MOON'S COMING OF AGE AS A NEW "WORLD" FOR MAN

Look up "world" in any dictionary and you will find a dozen or more definitions for each of many uses of the word. None of these goes to the essence of the concept, however. It is precisely that we find ourselves "too close to the trees to see the forest". If I could take a stab at it, I might define "World" as a **polycentric horizontal continuum**, or perhaps as a functionally integral ecosystem of communities.

The point is that our sense of "world" is not that of a physical place centered in ourselves – or in one local village – or in one settlement. Until there is a plurality of centers of activity on the Moon, however humbly small each is taken by itself, the Moon will be a "world", in the human sense, only potentially. A "world" is a "world" because it is shared.

Will the Moon ever become another "world" for man? Or will it remain just a big rock with a token garrison? Not to wonder! The wellsprings of a plurality of settlements and rural outposts is clearly present in the raw physical endowment. The nonuniform distribution of mineral resources, the diversity of terrain, the special advantages conferred by grid location (e.g. polar, limb, equatorial, and deep far-side sites) irrespective of mineralogical assets will all work towards the rise of multiple outposts and towns.

In addition to this distributive logic imposed by the economic geography of the Moon itself, there is another equally compelling logic within human community that will work to bud off additional settlements and outposts from the historic first beachhead. Only a plurality of towns will offer the political freedom that can only come from having options, the freedom, so to speak, of being able to vote with one's feet, by moving somewhere hopefully more congenial. With this divide-and-multiply inner compulsion will come institutional and cultural variety. Further, there will be the opportunity to pick different biospheric climates, flora and fauna, different urban plans, different architectures, and so on. And that brings us to elucidate yet another intrinsic parameter to the meaning of "World". A world is a continuum of places which are distinctively different from one another, not just by virtue of "nature" but especially as a result of human-added features.

With the multiplicity of human communities of whatever size comes an important "gain", that of distributed vulnerability for the population at large. No matter what disaster, natural or man-made may befall any individual human clustering, the "World" goes on. "World", then, also has the definitive connotation of overarching immortality – towns can come and go, not just people, but the "World" goes on.

"World", then, also connotes a certain inexhaustibility of relief from the local, the overfamiliar, the entrapment potential of any one particular nucleus of humanity. "World" is a continuum that includes a multiplicity of temporary or permanent escapes from one's own "horizontal" valley. "World" is a continuum of changing scenery, both natural and post-human. It is a whole which includes a multiplicity of opportunities to make a fresh start. We do not always need to exercise such opportunities. Often, it is enough to know that they are there. Without that ace up the sleeve, any one place becomes a prison, elegantly walled in by the lack of anywhere else to go.

No settlement, however thoughtfully planned, can stand alone, survive alone, be bearable alone. To have any chance of long term sanity and emotional health and overall morale, settlers will need to have available changes of scenery, of ambiance, of diversion. They will need places to vacation, places with which to trade, places with which to compete.

In brainstorming human settlement on the Moon, we would be wise to take a page from nature and not place all our eggs in one basket. A frontier "World" is a place in which one can get in on the beginnings, not just an historic once, but repetitively. In a very real sense, nothing we can do can turn an outpost into a genuine settlement, until, by virtue of other companion outposts, it does not stand alone. Until the Moon becomes a "world" any initial settlement will remain an unconsummated marriage of humanity and the host physical world. In this context the concept of "Rural Luna" is scarcely a far-

fetcher exercise in stretching the rational for “a” lunar settlement. Until “spacefaring humanity” has achieved a “world” of interdependent space locations, on the Moon, in free space, and elsewhere, we will not have truly left the cradle world; we will not have established an off-planet branching of humanity that could survive any global disaster on Earth. We, and Gaia, will not have successfully reproduced ourselves, and in failing to do so, will not have hedged our bet on species immortality.

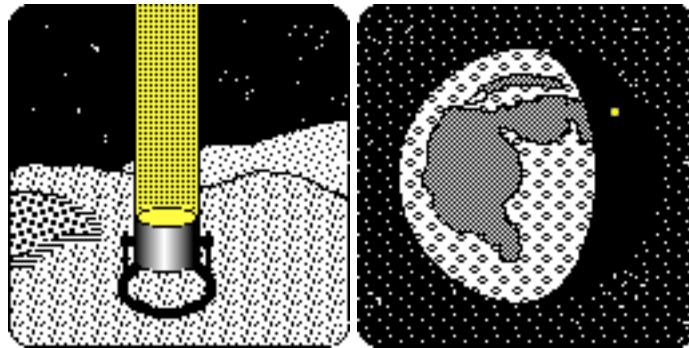
The habit of thinking in the preemptive singular is a recent deviation from common sense: “the” shuttle, “the” space station, “the” moonbase, “the” space agency. This deviant form of lemming-like decision making must be purged from our collective consciousness if we are to have any chance to avoid an Antarctica-like caricaturization of our space dream.

Finally, it has become commonplace in this age of exploration by robotic planetary probes to speak of “what were once just blobs of light unveiling themselves to be whole ‘worlds’ unto themselves.” But as worlds they are still each virginal. Many see this virginity as something to be preserved. But this eons long sleeping innocence awaits the kiss that will allow each such world to really flower as adoptive “mothers” to Man, and to Gaia. It could be that this will not happen repeatedly in space, not even just once, if the official and recently reaffirmed* self-deprecation that contraceptively rules our presence in the precursor “world” of Antarctica extends to keep sterile our activities off-planet.

PRM

[* We in the space movement have been vigilant about the defects in the proposed Moon Treaty, even alert enough to fight lest the Law of the Sea Treaty set a dangerous precedent. But we have been caught asleep at the wheel when a few years ago, we let the Antarctic Treaty be reconfirmed for thirty years more without protest. We may well have lost it all right there! Remember, fifty years after Little America, all we have is McMurdo Sound, lot’s of people, none of them settlers. PK]

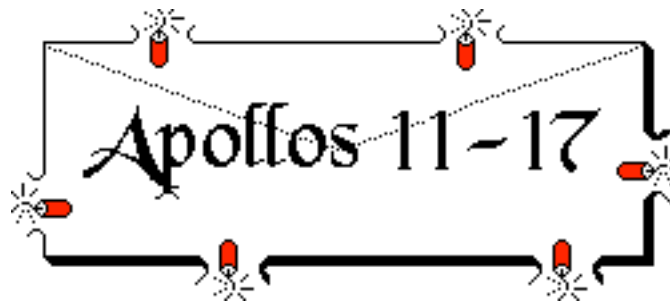
MMM #88 – September 1995



The Glint in the Moon’s Eye

One way to get across to people world wide, whether they be educated TV watchers or not, that there is something new going on on the Moon, would be to place a large beacon, pointed Earthward, near the launch pad of the beachhead Moon base (L). It would shine only during nightspan, being clearly visible in the unlit portion of the Moon’s nearside (R). What color would show up best? Red? Green might be less alarming, signifying plants as well as humans. Should there be messages flashed by Morse code? How many lumens, watts?

*in the (new) beginning, ...
(Starting over on the Moon)*



I. Bursting Apollo's "Envelope"

By Peter Kokh

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

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

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

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

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

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

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

A new beginning

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

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

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

- (1) We leave a habitat structure on the Moon, perhaps returning to an awaiting orbiting ferry (serving a function like Apollo's command modules) ascending on a cabinless platform (not unlike the Apollo rover) protected just by space suits.
- (2) Our habitat has room enough to walk around, and to sleep horizontally in cots or on air mattresses, and is big enough to boast both private and common room areas.
- (3) We "dig in" our shelter, placing it under a soil-shielded canopy or heaping soil directly upon it to make longer stays possible without high accumulative radiation exposure. Now we have a camp, a cabin, a cottage on the Moon, a permanent structure to come back to, and from which to expand in due course, as we learn to do so step by step, using primarily building materials made on location.
- (4) We leave an electronic beacon so that follow on missions can make instrumented landings at the same spot.

Then What?

- (5) We stay not only all "day" but past sunset, outlast the long two week night, and start a new lunar "day" before going home. This will be quite a feat, not unlike the first "overwintering" on Antarctica. Even with a nuke source for energy, we'll have less power than during the dayspan when we can tap sunlight as well. We'll have to switch from energy-intensive tasks during dayspan to manpower-intensive energy-light tasks during nightspan, establishing a lunar rhythm that may forever after give life on the Moon much of its characteristic flavor. In the process, we'll have to have in place an advanced, possibly bio-assisted, life support system regenerating our air and water supplies. We'll also have had to have demonstrated, probably in an unmanned dry run, thermal stability of the station through the nightspan. Shielding will help here too, minimizing exposure to the heat sink of space.
- (6) If we stay six weeks or more, we can plant some salad stuffs and bring them to harvest. The first feat for lunar farming and agriculture to come.
- (7) We might try some brief sorties outside the station during nightspan. That means headlights, that means lubricants that can take the cold – or magnetic bearings. That means heated spacesuits or an infrared radiating cage or a minimal cabin.
- (8) We bring along pilot oxygen production equipment, demonstration iron fine and gas scavenging equipment, a solar furnace to experiment with cast basalt, ceramics firings, iron sintering, and glass production. We have brought along some basic tools for fabricating sample test objects.
- (9) There is a parallel Earthside "Moon station" in which problems on the Moon can be addressed in close simulation, and in which terrestrial brainstormers can proactively outline suggested new experimental exploits for the lunar crew.

Exploring Metaphors

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

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

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

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

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

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

outpost: a station established at a distance from the main body; a post or settlement in a foreign environment.

station: (6) a place equipped for some particular kind of work, service, research, or activity, usually semipermanent

While all of these terms are applicable as far as they go, none of them are especially instructive. And most of them are static, not suggestive of leading anywhere, thus requiring separate justification of

any further steps, and thus likely to become self-limiting. We suggest that we space advocates who really want to see human

out-settlement wean ourselves of such terms as Moonbase, Lunar Outpost, etc. and look for more pregnant terms that suggest a sequence of phases that lead to something much more. If we find better terms we must popularize them and thus alter the culture in which space futures are discussed. **Words are not neutral.** We must pay attention to their downside or self-limiting connotations. We are in a battle for the soul of humanity. We have to stop using the weapons the enemy gives us and forge our own.

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

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

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

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

“Interface Beachhead” & “Settlement Incubator”

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

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

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

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

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

PRIZE LUNAR REAL ESTATE

Locations with special attractions – other than mineral wealth

By Peter Kokh

Impatience carries risks

There are those so impatient to return to the Moon that they disvalue any further robotic missions designed to reveal where the richest and most accessible resources lie as “money sink distractions”. Yet, to reduce the chances of the first human outpost becoming a ghost town in unseemly short order, the careful selection of a site especially capable of supporting viable economic activity is hardly

unimportant. Rather it is impatience that needs to be dismissed. Impatience always backfires. That's a Cosmic Law. There is no point in deliberately blindfolding ourselves and playing "Pin the Tail on the Donkey" with a Moon map as some apparently want to do.

The tasks of a First Outpost

At the same time, it is possible to argue that any good site will do to demonstrate the viability of a permanent human presence on the Moon. The task of such a beachhead is to survive the dayspans and nightspans, the heat and the cold, the radiation and solar storms and micrometeorite rain, the absence of a biosphere rich in organics and volatiles. Next the aim is to begin demonstrating an ability to use the resources that are common on the Moon to provide some continuing support and a respectable part of the wherewithal to expand.

Distribution of Lunar Resources

The Moon's major resources (oxygen, silicon, iron, aluminum, calcium, titanium, and magnesium) are distributed rather homogeneously (relative to their very uneven redistribution on Earth). So, the argument goes, we can always pick a second more advantageous site to begin industrial settlement in earnest. Indeed, one might argue, the lessons learned in the initial demonstrator outpost might warrant a fresh start else-where, rather than expand upon the trial and error dawn base.

While there is certainly merit to this argument, it is also likely that whether those planning and going on to deploy the first base care or not, additional robotic resource-finding missions are likely to be flown before the first outpost can be erected. In that case, it would be foolish not to take into consideration the knowledge those probes supply.

The relative advantages of some sites over others calls for careful consideration – "coastal" sites

Some general considerations can be made now. Both from a resource using and a tourist/film-making point of view, it would be stupid to locate the outpost either in the middle of crater-pocked highland terrain, or in the middle of the much flatter maria terrain — when by picking a "coastal" site the mineral and scenic diversity of both (highland and "sea") are present. Happily, innumerable sites fit this requirement.

Early Iron Extraction and Production, Basalt-based industries

If early industrial activity beyond oxygen extraction is likely to center on iron as the easiest element to extract and produce, we already have fair evidence of extensive areas that fit the bill. We'd be suicidally foolish to locate elsewhere. As basalt industries are also likely to start up early, mare/coastal areas would seem to have priority.

Public Awareness Potential

Another point of convergence is maximizing public interest and awareness. This should be important both to those who would like to see a government Moonbase (in the mold of Antarctica's McMurdo Sound) and those who would like to see a civilian commercial outpost (like most every for real burg on Earth). One sure way of doing this is to locate the base in an area that can easily be identified by the trained naked eye, or at least in binoculars. Perhaps others in the habit of studying the Moon with the naked eye might not concur, but the feature I find easiest to locate at all phases of the Moon visible in early to middle night hours is the Sea of Crises, Mare Crisium, to the north east of center. This oval Mare, the size of Wisconsin and Upper Michigan together, is clearly distinct from the "chain of seas" that run into each other: Fertility, Tranquility, Serenity, Rains, the Ocean of Storms, etc. I am aware of no one else who is partial to Crisium. Other proposed locations in Fertility, Tranquility, Serenity, Imbrium, the crater Alphonsus etc. can be picked out by the trained eye easily enough in binoculars, but that makes them unidentifiable for the masses. Anyone can learn to spot Crisium immediately. Somewhere along the shore of Mare Crisium, along the highlands separating it from Mare Tranquillitatis or Mare Fecunditatis could make a fair site. Of course, this is only one consideration and must be weighed along with others.

Dayspan naked eye identifiability is not the only PR trick that promises to build public awareness. A nightspan beacon near the outpost, beaming enough lumens Earthward to be clearly picked out, would certainly command much more attention. This would suggest placing the outpost in a part of the Moon that is usually not illuminated when the Moon is above the horizon in early evening hours – in other words, well into the western hemisphere (coastal/shore areas of western Oceanus Procellarum, the Ocean of Storms, or in the Aristarchus area for example). In contrast, a beacon in any of the eastern

seas (Tranquility, Fertility, Crisium, etc.) would not be visible until the waning (post full) Moon that rises later in the evening and would be noticed by far fewer people.

Improved vs. Unimproved Sites

On Earth we distinguish between improved and unimproved sites. The later lack electrical and water utility access. But even unimproved sites on Earth have atmosphere and access to at least some rain. No site on the Moon has as much, every lunar site being radically unimproved.

Shade

Yet some sites have assets, beyond minerals, that other sites do not, such as appreciable part-time (and rarely, full time) shade. This can be important in planning thermal equilibrium maintenance with the placement of heat rejecting radiators etc. Rille walls and crater walls and escarpments all provide part time shade depending on the local path of the Sun across the sky. In general such minimally improved sites are scattered everywhere, but are the more densely located the nearer to the poles where the maximum elevation of the Sun over the equatorward horizon is lower. This would seem to directly compete with the landing/take off economy of equatorial sites. But keep in mind, with the Moon's lethargic rate of rotation, the touted desirability of equatorial sites is grossly exaggerated.

"Lee" Vacuum — Lavatubes

More significant an asset than shade is true "lee" vacuum, where there are surfaces never exposed to the lunar sky, and thus always protected from cosmic radiation, solar ultraviolet, solar storms, and the micrometeorite rain as well as wild day-night sunshine-shade temperature swings. Such areas will be ideal for warehousing and garage space and unpressurized industrial operations. They exist underground.

The Moon has no limestone caves made by running and dripping water. But it does have lavatubes on the order of many tens of meters wide and high, many tens of kilometers long. These substantial lee voids are currently known only from indirect, yet indisputable evidence. Winding valleys, aka sinuous rilles, are a related feature, made from rivers of very fluid lava. Many rille valleys have bridged sections that suggests the visible valleys are near-surface lava tubes with collapsed roofs and that the "bridges" are intact tube sections.

Elsewhere we see winding chains of rimless craters that can only be collapse pits where parts of a largely intact lava tube below have fallen in. The inference is that elsewhere, there are wholly uncollapsed lavatubes. As the mare basin-filling lava sheets were laid down in distinct episodes with lava tubes likely forming in each layer, there may be many intact lavatubes well below the surface layers in some lunar seas.

Where are these lavatubes and their "lee vacuum" to be found? In the maria, mostly near coastal areas! While we are a long way from identifying all such features, we can locate a base in a coastal region with partially collapsed rilles in the likelihood of finding usable intact tube sections nearby.

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OVERNIGHTING: CONSUMMATING THE MOON/BASE MARRIAGE

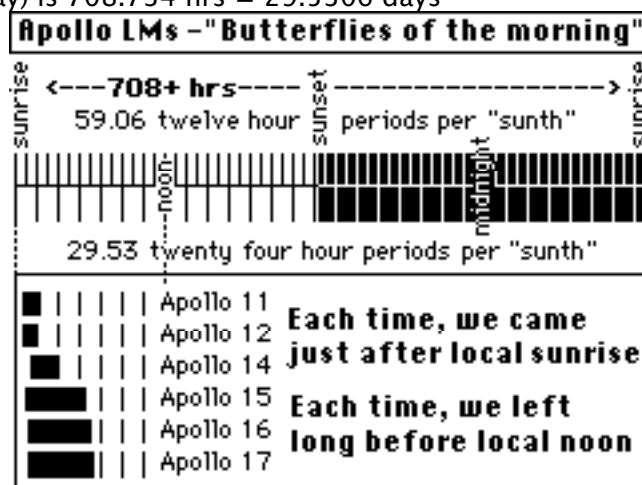
By Peter Kokh

Dawn Touchdowns, Pre-noon Lift-offs

For sake of best long-shadow lighting conditions as well as heat management, All the Apollo missions landed shortly after local sunrise, and as if subconsciously frightened senseless of nightfall, left well before local noon. We haven't come close to experiencing a whole lunar dayspan/nightspan cycle! Here are the figures for each mission.

- A11 TD 10.93 hrs after local sunrise LO after 21.60 hrs after local sunrise
(like 6:22–7:06 am on Earth with 6:00 am sunrise)
- A12 TD 10.12 hrs after local sunrise LO after 19.52 after local sunrise
(like 6:21–7:01 am on Earth with 6:00 am sunrise)
- A14 TD 20.75 hrs after local sunrise LO after 33.51 after local sunrise
(like 6:42–7:50 am on Earth with 6:00 am sunrise)
- A15 TD 14.04 hrs after local sunrise LO after 68.91 after local sunrise
(like 6:29–8:49 am on Earth with 6:00 am sunrise)
- A16 TD 17.82 hrs after local sunrise LO after 71.04 after local sunrise
(like 6:36–9:00 am on Earth with 6:00 am sunrise)
- A17 TD 16.8 hrs after local sunrise LO after 75.00 after local sunrise
(like 6:34–9:06 am on Earth with 6:00 am sunrise)

NOTE: Lunar Sunrise to Sunset is 354.367 hrs = 14.7653 days
Full Sunth (local day) is 708.734 hrs = 29.5306 days



This is a pattern similar to early sorties to Antarctica.

There, we came after the spring pack-ice break-up and left well before the fall freeze-up – for the first two decades. It wasn't until Byrd set up Little America in 1929 [a site abandoned 30 years later in '59 as U.S. Antarctic operations concentrated on McMurdo Sound] that we took the plunge and "overwintered". That was quite some hurdle, mentally and emotionally, as well as operationally and logistically. Now we face the same hurdle on the Moon. But until we do it, all our talk of "permanent presence" is just so much empty macho bravado.

In the case of Little America, the major hurdles to be overcome were the need to build up during the summer months enough fuel (heat, power, and vehicles) and food reserves to last the long cold winter night months when resupply would be impossible. Rescue would also be impossible, meaning medical supplies and kits had to be more adequate, and medical personnel more fully trained. On the Moon the challenge will be similar although the nightspan is only a twelfth as long.

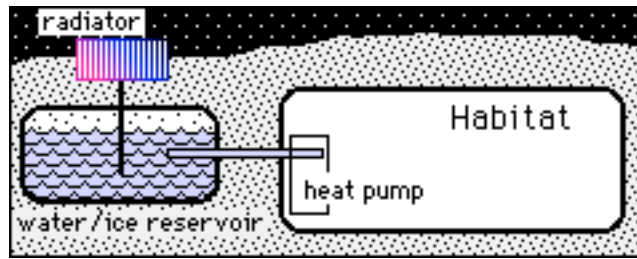
Thermal management

Surface temperatures drop drastically and quickly after lunar sunset. But, these are surface effects only. The powdery soil is a poor conductor, and a poor reservoir, of either heat or cold. A couple of meters down, below the blanket of shielding soil, temperatures remain about -4° F or -20° C all the time.

Most expect a heat buildup within the buried habitat, heat from living, heat from operations, that will not be drawn off by the surrounding soil as fast as it is generated – even at night. If an equation of heat inputs and losses shows a net heat rise even during nightspan, a system of external heat-shedding radiators will be necessary.

If, however, because available power during nightspan means powered down operations, and if that in turn means a thermal deficit during nightspan, then some sort of thermal heat sink accessed by

a heat pump might not be a bad idea. We'll have, or should have, the former – in the form of water reserves. A large reserve tank can be buried in the soil not far from the habitat. Heat from the water would be pumped into the habitat by nightspan, the direction reversed for dayspan cooling. A net heat excess over the whole dayspan/nightspan cycle would then be shed by external radiators.



If we don't bring along, find, or generate (i.e. adding hydrogen to locally produced oxygen, probably in fuel cells to produce night power and water both), enough water to make such a heat-pump accessible water reservoir work, then our plans to make our presence "permanent" are in big trouble.

Successful thermal management will depend largely on how much care is taken to isolate major heat-producing activities from the habitat areas. This means automated unpressurized processing and manufacturing plants, saving low temperature aspects of production (finishing, assembly, etc.) for occupied areas.

Nightspan Power

Many suggest solving the nightspan power problem by bringing along a small nuclear power unit. Even if the legal and political hurdles can be overcome (e.g. by having the Russians contribute this system), the point is missed. No matter how big the nuke, there will still be less power available during nightspan than during dayspan for the simple reason that during the latter, the Sun also shines, its heat ready to do work – simply and cheaply.

The Sun can provide nightspan power in these ways:

- a. Solar heat can be used via several processes to produce oxygen from moon rock by dayspan. During night-span this oxygen is combined with hydrogen brought from Earth, in fuel cells, to produce power – with pure potable water as the byproduct.
- b. If necessary, solar power can also be used during dayspan to electrolyze a portion of the water reserves back into hydrogen and oxygen for nightspan fuel cell fuel. (In addition, the Sun's raw ultra-violet rays can help purify the remaining water reserves under cover of UV-transparent quartz.)
- c. If there is an early cast basalt industry to provide paving blocks and other low performance items useful to the expanding base, possibly as a sideline to oxygen production through heating the moon rock, this would open another road for Sun and water to work synergistically to provide nightspan power. If during dayspan, when the solar concentrators power these industries, there builds up an excess residual pool of molten rock and this is kept shielded from the heat-sucking night sky in an underground reservoir, the residual heat of this "magma pool" can be tapped to produce steam to run the base's nightspan generators. This is the idea of LUNAX director David Dunlop. A refractory lining of aluminum oxide would make such a magma-pool reservoir more efficient, but might not be absolutely necessary.

Mark Reiff of General Space Corporation suggests another form of lunar heat pump. If vibroacoustic testing locates a relatively small underground void (cavern) near the surface (less than 100 feet), this can be accessed by drilling. The natural reservoir can then be filled with a thermally conductive material (he suggests smelting regolith into molten aluminum). The thermal properties of the available material should drive the purity requirements. The material would be allowed to reach an equilibrium (cool). Next you would set up a thermal dynamic generator (Sterling cycle would work good) with your heat source on one end and the newly created heat sink connected to the other. You could shade the generator and the top of the heat sink to even provide power by dayspan too. [Smelting aluminum, however, is not likely to be an early outpost technology – Ed.]

The Sun and Water, then, seem to be the simple and elegant basic ingredients for a nightspan power system (as well as maintaining thermal equilibrium). Elaborate and expensive plans for providing nightspan power (or maintaining thermal equilibrium) by other higher tech means seem foolish.

The division of labor into hot in-vacuum and cool in-habitat chores (see above) in order to assist in thermal management will also work neatly to separate man-hours into energy-intensive dayspan aspects and labor-intensive nightspan aspects of the total production and operations cycles.

I have suggested that this fortnightly change of pace will become a well-liked feature of lunar life. Some have seen it as a burden to be avoided. Do not forget that on the Moon there are no seasons, no daily changes of weather, both of which add spice and interest and renewal to living on Earth. If this nightspan power "deficit" were ever to be effectively eliminated, the biggest source of rhythm and change of pace would be gone with it. Productivity gains would be temporary as morale slowly plummeted from routine, boredom, ennui.

Other nightspan power solutions frequently proposed are well down the road, something for later generation advanced settlements to consider. These include solar power satellites, lunar solar array networks (one over the nearest pole makes the most sense as it would be in sunlight whenever the outpost is experiencing nightspan), helium-3 fusion plants, and, oh yes, lunar hydroelectric [see * below].

Air/water/waste management

Overnighting will also require much more capable recycling systems than did missions only intended to spend a couple of days on the morning Sun lit surface. Some water recycling chores can be solar-operated, as suggested above. By nightspan, used water could simply accumulate; or, freezing (by sky exposure) could work to separate out some impurities.

Human solid wastes could be stored out-vac, left to freeze in shaded sanitary containers. Rather than be a problem for eventual disposal, such compostable organics-rich material will become a banked resource of great value for the eventual commencement of regolith-soil based agriculture, once creation of significantly cheaper pressurized expansion volume becomes possible using on site produced building materials.

Other "Overnighting" Needs

Plan as we will to stock up by dayspan for a dayspan-only logistics operation of resupply and manpower relief from Earth, we will be prudent to allow for the possibility of night landings and launches. Once we can land on a dime using signal clues rather than visual ones, this should be no big deal. It does mean, however, that the outpost's "spaceport" be more than a simple designated circle in the sand. It will need to be equipped with beacons and lights and radio.

For this and who knows how many other contingencies, a service vehicle that can operate at night is also a must. This means more than headlights. It means power supplies, motive systems, and lubricants that can withstand temperatures of -200° F or -130° C with no problem.

Overnighting Measures, a Test of Outpost Design

Any approach to lunar outpost design, NASA/Inter-national or commercial, in which every aspect does not reflect the needs of "overnighting" begs to fail. If you are honest, you will realize that some of the above capacities are not self-obvious if you conveniently ignore the fact that some time after your base setup landing, the Sun will set, and stay set for almost fifteen days, over and over again every sunth, forever.

Relevant Readings from MMM back issues

[Republished in MMM Classics #1] – MMM # 7, JUL '87, "POWERCO"

[Republished in MMM Classics #4] – MMM # 31, DEC '89, pp. 3-5, "Ventures of the Rille People" (Prinzton design study report), V. * Multiple Energy Sources.

[Republished in MMM Classics #5] – MMM # 43, MAR '91, pp. 4-5. "NIGHTSPAN"

Re^{visit}ing the Moon Buggy



Would lunar rovers left on the Moon still be in working condition when we return?

By Bryce Walden, Oregon Moonbase (bwalden@aol.com) [reprinted in MMM with permission]
[response to a screenwriter's question on America OnLine]

General contractor for the Lunar Roving Vehicle (LRV) was Boeing; GM Delco made the electronics. The LRV was first used on Apollo 15 at Hadley Rille, and in all subsequent missions. The chassis was aluminum. The essential "buggy" massed 400–600 lbsm (pounds–mass) (180–270 kilo–grams) depending on equipment. It could carry equipment, astronauts, and payload up to 1100 lbsm (499 kilo–grams), more than twice its own weight. Yet it was not strong enough to hold the astronauts on Earth.

Top speed mentioned by my source was 14 kph (8.7 mph); the speedometer was calibrated 0–20 kph (0–12.4 mph). Average speed on all three missions using the LRV was 5.17 mph (9.1 kph). Average for Apollo 17 was 5.0 mph (8.0 kph), total distance traveled was 22.3 miles (35.9 kilometers), and total time driving was 4:26 hours.

Power was supplied by 2 silver–zinc batteries, each 36v, 121 amp–hours per battery, encased in magnesium, then enclosed by thermal blankets and dust covers. Each battery had a relief valve for protection against excessive internal pressure. Thermal control was critical: the batteries had to be maintained between 40° F (4° Celsius) and 125° F (52° Celsius). The only practical method of heat rejection in the vacuum was by thermal radiation. Unfortunately, the slightest amount of lunar dust on the radiators (essentially mirrors) would "effectively destroy" their ability to perform. For this reason the radiators were kept closed during activities, to be opened manually by astronauts after "parking" for the "night." "During operation, heat generated was stored in heat sinks consisting of two LRV batteries and tanks containing wax–like phase change material." According to Gene Cernan and Jack Schmitt, "If you take a couple more batteries up there, that thing would just keep going...."

However, these guys aren't Moon Buggy Mechanics. Other astronauts have been known to say the buggy had used up all warranties by the end of the mission (5 days or 250,000 miles....). Besides the batteries, the flexible spline inside each wheel hub, part of the kinetic power transmission system, may have degraded. Countless thermal cycles of the vehicle between lunar day (+250° F, 121° Celsius) and lunar night (–0° F, –157° Celsius) will take their toll on structural elements, electronics, and other system parts. There is also the possibility of radiation damage to the control electronics. Of course, it might work, for a little while --perhaps a heroic last gasp. With fresh batteries, of course. That overpressure release probably let vital elements escape as the batteries heated to lunar daytime temperatures.

One other interesting note is that the LRV had an inertial navigation device that always pointed toward the LEM (bearing and distance), so the astronauts would not have to guess, in the austere and misleading lunar environment (ever taken a walk in the desert?), the quickest way back to the base. They also did not have to stay in sight of the LEM.

Lunar rover data and quotes are from "The Lunar Roving Vehicle: A Historical Perspective" by Saverio F. Morea, Director, Research and Technology Office, NASA Marshall Space Flight Center, Alabama, where the LRV was tested. The paper was presented at the second Lunar Bases and Space Activities of the 21st Century conference, April 5–7 1988, Houston TX. Contribution No. LBS–88–203.

That being said, I don't think we should depend on or plan to use any of the one–shot equipment sent up with Apollo. I prefer the idea of fencing it off and preserving these first explorations as well as possible. We should be sensitive to other sites of interest, as well.

BW

PERSONNEL

PERSONNEL: From Scout Crews to Pioneer Settlers

Expanding “tours of duty,” “reenlistment” options, partners & pregnancies, cabin fever prevention, etc.

By Peter Kokh

Expectations from our long-running experiences on Mir should give us confidence for similar manning and crew rotation patterns on the Moon. In its one-sixth Earth-normal gravity (“sixthweight”), any physiological deterioration should both proceed more slowly and be accumulatively less severe than in ambient zero-G. In following this pattern, we might expect some lunar base personnel to have longer tours of duty, while other visiting “mission specialists” who have come to oversee relatively short tests of pilot demonstration processing equipment, for example, may return to Earth in short order.

There are several reasons why personnel may rotate at a slower rate than the rhythm of Earth-Moon support and resupply flights might seem to allow:

- (1) not bringing replacement personnel frees up allowable net payload mass for extra badly needed equipment.
- (2) not returning personnel makes room for extra “export” cargo from the Moon:
 - (a) lunar liquid oxygen for delivery to LEO to refuel the Earth-Moon ferry
 - (b) loads of regolith samples for delivery to Earth’s surface where ongoing processing experiments can be done more cheaply and more thoroughly, i.e. with lower gross man-hour support costs and in better equipped laboratories.
- (3) if the lunar descent vehicle is built as we’ve suggested, with the crew cabin underslung and equipped with a surface locomotion chassis that can be winched to the surface and taxi to the outpost [“frog” and “toad” “amphibious” lunar landers are introduced in MMM # 48 SEP ‘91, pp. 4–6 “HOSTELS: Lowering the Threshold for Lunar Occupancy,” Part I – MMM Classics #5] every descent module that returns crewless means an extra surface vehicle at the disposal of the outpost.
- (4) In general, average on-the-Moon labor support costs will come down as the amount of productive man-hours per ticket of passage goes up.

With all these forces operating to encourage extension of lunar surface duty times, outpost managers, both on site and on Earth, will be motivated to provide perks and incentives for voluntary extension of planned tours of duty. Moon duty will be exciting and prestigious at first, with no shortage of volunteers. But as duty time wears on, the view out the window less dominated by Earth, more by sterile, barren, unforgiving, and lonely moonscapes of colorless grays, lunar base personnel will be glad to get out of their sardine can quarters, be relieved of their cabin fever, and return “home.”

From this humble beginning to an era when men and women will come intent upon staying the rest of their lives is one tremendous jump. But the long road from limited mission scouts to pioneer settlers starts right here, with the need on the several counts mentioned above to encourage voluntary, but still not indefinite, extensions of contracted duty time.

People put up with what they have to. If the next opportunity to “get out of here” is some time off, one grins and bears the restrictions, the confinement, and the sacrifices with or without a smile. But if ships are returning to Earth on a regular basis and one’s “moon duty” has already “worn thin,” then the desire to be aboard the next ship home will begin to interfere with one’s effectiveness. Perks, extra amenities, and other incentives to make continued surface duty more bearable will be absolutely necessary.

Pay: we start with the obvious: money, the worth-while-maker. As duty extensions are cheaper than crew replacement, some of the “savings” realized are properly shared with those agreeing to stay on, in terms of higher wage rates. Wages can be sent to one’s Earthside family, or accumulate in a terrestrial bank account. But there are other forms of compensation.

The “re-upper” can be rewarded with “import credits” e.g. the right to request added mementos, pastime materials, or favorite food delicacies to be on the next ship up. One can acquire seniority for bidding on desirable assignments. One can be admitted to the decision making councils. One can be granted more “flexitime,” leeway in personally scheduling work time and free time.

Time off: sabbatical week “vacations” would be a very special perk, one that the “reupper” can use to explore in greater depth any hobbies or interests — experimenting with lunar art/craft materials, dance forms that go with the grain of sixthweight, exploring and developing confined space sixth-weight sports ideas; music, poetry, literature, and writing articles for hire reporting on life on the Moon. It is important to realize that all such activity can be indirectly productive for the basehold as a whole if and in so far as it opens up more possibilities for other personnel to enjoy their stays.

Attention to ambiance. Not all the perks should be reserved for those who agree to duty extensions. By then the psychological damage from unnecessarily spartan conditions may be irreversible. The outpost can be made both ergonomic and functionally pleasant at little or no extra weight penalty or cost simply by thoughtful design. Crew quarters can be individually decorated, and easily redecorable to suit the tastes of new occupants. There should be varied and redoable decor in the common areas. There should be cubbyholes other than one’s own cramped berthspace in which to retreat. Attention should be paid to acoustics so that one has the choice of back-ground music or silence or his/her own favorite blends.

Rotation of assignments: no matter what one’s specialty, there should be the opportunity for shot-in-the-arm routine-busting assignments. Those regularly in the field can be given inside duty for relief. Vice versa, those stuck in labs and workstations can be given periodic field duty.

Leisure time opportunities: the outpost should have a good audiovisual and literature library, in the lightest weight storage form, of course. There should also be some traditional art and craft media and the opportunity to explore working with on site materials. Requests should be honored when feasible for “time off together” for those wanting to explore dance or sport or other “exercise” options. There should be “real” opportunities as well for continuing self-education, personal or occupational, for credit when desirable.

A bit of Earth: relief duty in the outpost farm, even if nothing but a compact hydroponics closet operation, will be welcome to most. In addition, an abundance of well-chosen “house plants” will not only help keep the air “fresh and sweet,” but provide a psychological filter against the barren and sterile surroundings outvac – especially if arranged in the foreground of any window or viewing port. Available nooks and crannies can be the opportunity for “pocket parks,” even “forests” of bonsai evergreens.

Water reserves can be put to work as well. Fountains and wallside waterfalls add both soothing white noise to help drown out the non-symphonic hums of assorted equipment, and to keep the air comfortable and rain-fresh. Aquaria can add the further comfort of “wildlife,” color, and visual relief. Another opportunity for “wildlife” will arise once the outpost “farm” reaches the stage where natural pollination would be helpful. Bees, butterflies, and hummingbirds are candidates.

Scarcely anything, however, is more important for morale, day in and day out, than menu diversity and good tasting food. Bland nutritional balance is hardly enough – not out of the ivory tower. The outpost pantry should be kept well-stocked with herbs, spices, and peppers.

Toward “Social Normalcy”: the desire of outpost mission planners to control and otherwise restrict the range of “permissible” social activities will be strong. On the one hand there is the legitimate desire to have things run smoothly and discourage behavior that can be disruptive. On the other hand there is the illegitimate pressure that comes from having the rest of the world looking over your shoulder with their assorted hangups. The solution to both has to be a very real degree of privacy with limited and scheduled public “telepresence” along with a degree of discretion given to on site authority.

While the variety of social interactions will become measurably more satisfying as basehold population increases from shy of a dozen towards a hundredfold or more, nothing should be done to control or restrict spontaneous sexual liaisons, romances, and relationships so long as they do not begin to interfere with work or with the morale of the rest of the personnel. That said, it remains a pretty good truism that fraternization “at work” is a bad game plan, full of pitfalls and well documented by horror stories. Nevertheless it happens.

Pregnancies will be strongly discouraged at first (cf. the ABC movie “Plymouth”), and perhaps be reason for early termination of tour. Yet sooner or later this is a plunge that must be taken. We cannot know for sure that the Moon is a potential long term new home for man until the second generation of native born turns out healthy and fertile.

A more serious potential problem is the development of a medical condition that would make survival of a trip back to Earth problematic. It may never happen.

What to do with someone who has done something unforgivably antisocial or outright criminal is an eventuality more likely to occur. “Out the airlock without a spacesuit” is not an option. Confinement to quarters (makeshift brig) means a loss of productivity. The alternative may be to assign the person to undesirable but necessary duties, inside or outvac. Menu and free time restrictions might be effective penalties. No amount of prior screening can prevent trouble altogether.

Sooner or later someone will die on the Moon either by accident, by sudden illness, or by foul play. Shipment of the remains to Earth should not be automatic. The person in question will have signed a living will which states his or her preferences. Internment on the Moon should be an option. Nor need this mean “burial.” If the outpost has a furnace that can serve as a crematorium, one can specify his/her ashes to spread inside in the outpost “flower garden” or “pocket park” or outvac in some chosen or favorite spot. If not, another option is simple surface internment, under UV-proof glass, otherwise exposed to the vacuum, and the stars. More than any flag, a burial site makes a place, however desolate, forever human.

Longer term. So much for beginnings. Our humble lunar outpost will have to number more than a hundred before there is enough diversity of talent, occupation, opportunity, and social interaction to make indefinite stays tolerable even for the hearty few.

The mini offspring biosphere with which the frontier community reencradles itself will have had to become much more massive, self-regulating, and forgiving before all but the most determined will be willing to give up ever returning to the lush green hills of Earth. We will have had to have progressed from outpost-with-houseplants to biosphere-with-farm-and-farm-village, and a tad of compatible or insulated industry on the side.

Economically, we will have to be manufacturing on location a visibly large portion of our needs, particularly expansion shelter and furnishings. Thriving indigenous arts and crafts will begin to endear pioneers to their new world be home and start to add to the list of things they would have to “give up” were they to return to Earth. When this list becomes personally more cogent than the list of still missed things they gave up to come to the Moon, the balance will be tipped.

We will have had to made the commitment to the less direct productivity of child rearing and retirement. And perhaps these two needs can take care of each other. Parents can work while retiree “grandparent” volunteers (with enough energy) can teach and raise the young. In general, there must be programs to keep all citizens as productive as possible. In this light, retirement becomes more of a shifting of gears, of switching to less stressful, more relaxed, less demanding “half-time” assignments. Besides teaching, administrative paper-pushing duties come to mind. There will be other things. Everyone must, and must be given a full range of opportunities to, pull his or her weight in the forever upward struggling pioneer frontier community.

Population will have to grow too before their will be enough of a gene pool upon which to base a stable permanent population, if, for some reason, the traffic from Earth should be cut off, forcing the infant community to go it alone, hopefully in economic interdependence with other similarly stranded off-Earth pockets of humanity. While this seems far off, it is a scenario which has long motivated space supporters.

The journey of a thousand miles begins with the first step. We’ve tried here to outline some of these first steps, as well as some other forks in the road a bit further along. If it is going to all happen, we will have to consciously take these steps in a timely fashion. EMMA

Rethinking the **MOON BUGGY**

Reflections from Dale Amon

[\[amon@vnl.com\]](mailto:amon@vnl.com) – Dale, chair of the 1987 “Merger” ISDC in Pittsburgh, now lives in Belfast, Northern Ireland.]

Who would want to [build new lunar rovers from the old Apollo era plans]??? By today's standards the electronics on that thing are a science fair project...

Replace the frame with composites from Scaled Composites. The electric motors will be a fraction of the size and weight because magnet materials have improved vastly since then. Storage technology has not improved by as great a degree but still, it has advanced. We'll have commercial micro-machine accelerometers on the market soon, so the navigation hardware will be built right onto the

chip with the electronic interface. The comm gear has shrunk to nearly nothing. Compare a walkie talkie in a 60's era Edmund Scientific catalog with what you can pick up down at your local Tandy Radio Shack. R/C toys have better radio equipment than some of those 60's comm units...

And then, most importantly of all – we know the environment it is to work in and have those old rovers, their problems and performance as an initial data point. And that data point is basically that it is no big deal building one. They are a piece of kit that a hobbyist could successfully build. It doesn't take an aerospace company to build an electric dune buggy.

Just a bit of caution on vacuum, a bit of thought on rad hardening, a bit of care on temperature range... And you needn't bother about outgassing of your materials. They'll never be inside your breathing space so who cares? That makes it a lot easier.

Oh, and some care in packaging may be required to insure it isn't damaged by the vibration. I remember ruining a tire on my DT400 by not tying the tire down when hauling it in a trailer behind my car. Tire spun from the vibration and wore the nobbies bald...

From Rovers to Cycles — Human Power

While walking home recently one night I remembered some thoughts I had on lunar rovers a number of years back. There will be a need for different sorts of vehicles, and undoubtedly large hauling vehicles, whenever they are required, will need a good power source. Whether that be fuel cell, battery, solar power, beamed power or some mix I won't go into here. But the type of vehicle needed for a small relatively self sufficient group should have a number of characteristics that few of the designs in the literature ever consider.

- fi The motive source should be 100% field repairable preferably with only a few tools and simple spare parts.

- fi Spare parts should be such that they can be manufactured locally from small amounts of raw materials.

- fi The vehicle should have a fail safe criteria that it can bring the driver home under almost any circumstances in which the driver is still capable of driving.

- fi It must use indigenous energy supplies.

Now if you look at these requirements through the old fashioned NASA eyes, you will come up with a billion dollar project. If you look at it with the eyes of an engineer, you immediately come to the conclusion that a human powered vehicle is just the ticket.

Research backs this up. In a Scientific American issue on Human Powered Vehicles a number of years ago, an article on bicycles had an extra data point for the performance of a vehicle on the Moon. A racing biker, with no air resistance and 1/6 g could break 1000 km/h in sprints. A normal, healthy person could cruise at over 100 km/h all day, and could easily pull a trailer load at the equivalent of typical Earth-bound auto driving speeds.

The form of the vehicle is the recumbent bicycle like that used by Stephen K Roberts (Computing Across America). And in fact, he would probably be the best person to speak to on the design of a lunar rover. He crossed the USA from end to end several times on his recumbent, traveling up and down through the Rockies, keeping up reasonable highway speeds – and all the while with a trailer that included solar power gathering and a satellite uplink so he could type on the keyboard in front of him (while peddling) and submit articles to magazines that funded his journeys. He also had navigation and maps built into his console processor. I don't think there is anything that a lunar rover built for days of unsupported prospecting would need that he didn't do 5–6 years ago.

Now, that is not to say there aren't issues unique to the Moon. There is the issue of traction and off road travel which will drive the gearing ratios, axle loading, weight and balance, and wheel design.

Braking will have to be dynamic, feeding the energy back into a dynamo. Normal friction brakes are a bad idea for two reasons – 1) The abrasiveness of the regolith. 2) Brake cooling is purely by radiation to the background and conduction through the frame. Radiators are a problem as has been suggested before; and since I expect the frame to be composites, conduction is not very good either.

Gears and chains and deraileurs will have to be very robust and spares will be required. A design that can be field welded would be a good idea. Better to trade off a bit of elegance and performance for field maintainability. These parts can be built very ruggedly (I'm not talking about racing bikes here!!) and would need to be able to withstand the rigors of large temperature swings and abrasive particles.

One could seal them, but then it is more difficult to field strip. And not to mention which, without herculean efforts the lunar grit will get in anyway. If anyone out there was in Desert Storm...

Another area of concern is space suit cooling. The loads will not be excessive under normal cruising since the peddling is only enough to replace frictional losses.

Use of a small motor like that in a mini bike could solve a number of problems (if they don't add too much complexity on their own). The motor could be the means by which braking returns energy to storage. Energy can be recovered on downhill stretches and used to ease uphill travel. It also can reduce the heat loading on the space suit during acceleration from a standing start, or indeed any acceleration under load. The motor would, of course, need to be built such that it can be disconnected from the system entirely if it fails. The over all system would have to be able to get the lunan back home regardless. So think of it only as a luxury item on the bike.

The suit would be a live-in suit, so that puts some extra design load on it. You might have to do better than a diaper if you're going to be out for a week... But this is a problem that needs to be solved anyway. The Stars Wars rovers that some NASA scenarios show us are not going to be feasible on any realistic budget, and in any case you'd only be able to afford one of them for the same price as giving every lunan their own personal lunabike.

It seems wholly superior to any rover concept I've yet to see. Just about anyone out there could have run circles around the Lunar Rover and been out 20 km and back before it was barely out of sight of the LEM...

Ah, you say, bikes are good on highways, but off-road you're going to want a trike! The lunar surface has huge areas that are much like beaches and dunes. Covered with hardpacked fine regolith that follows the contours of the land in a very smooth and gently rolling fashion. This is not to say that crater rims and such are quite the same – but large tracts of the Moon should be easily negotiable.

As to bike vs. trike, there is no inference above, of a two wheel design – in fact I believe the recumbents are usually trikes. At least the Robertson one that I saw in 1989 was... DA

Out-vac trike-suits are a challenge

By Peter Kokh

Sounds delightfully low-tech, doesn't it? Tired and stressed out after a long day's work in your lunar office, mine, or factory? Just don your out-vac trike suit and head for the airlock and get some heal-all unwinding exercise! Reminds me of an Arthur C. Clarke's story where the hero does a kangaroo-lope to safety 600 km across Mare Imbrium in just a spacesuit.

The question arises: without an open air heat sink, where does all the body heat generated by such exertion go? An out-vac triking suit needs not only to be self-contained (in RV-camper-trailer talk that means "with toilet"), but able to handle/ shed internally-generated heat and perspiration as well. That also means being able to keep the wearer from getting a chill soaked in his/her own sweat once the exertion is over. Perhaps the suit's insulation material could be an eutectic salt in a quilt of pocket cells, melting to absorb internally-generated heat, solidifying to release it – automatically, on demand.
PK

Or Perhaps a "Buppet" Bike

By Phil Chapman <pchapman@BIX.com> with permission, from a post on Artemis-list

[* **Buppet**: etym. from "**Body Puppet**] (on the analogy of Muppet from Mitten Puppet)

Note: "buppet" is the editor's word, not the writers

See MMM # 89 OCT '95: "Dust Control" pp. 6-7 – Republished in MMM Classics #9]

Having tried both [an EVA suit and a diver's dry suit], let me tell you that a pressurized conventional spacesuit is much more restricting than a drysuit.

Spacesuit design has been hampered by thinking of it only as a garment. It is also a small space vehicle. A conventional suit is no place to be for more than a few hours. For longer durations, you need to be able to pull your arms in so that you can scratch, or eat, or sleep, or void. This suggests that the lunabike should be integrated with the suit -- in other words, the suit would be a lightweight pressurized canister with wheels (4, for stability), with a shirtsleeve internal environment for pedaling and liv-

ing. The canister would be equipped with pressurized gloves, waldoes or other attached tools for manipulating the external environment.

It might be necessary to carry a conventional suit, donable inside the canister, so that you could get out and get under if something broke, or go climb that cliff over there (where, as Arthur Clarke has told us, The Sentinel is waiting), or, in extremis, walk home. For routine use, (such as getting from one pressurized dome to another) the mobile canister alone might be sufficient. The real safety reason for carrying a conventional suit is to avoid potentially fatal single-point failure modes, an objective that might be met by careful design of the canister/bike alone. PC

No, what we need is a Volkscycle!

Response from Dale Amon to Chapman's suggestion

[What I have in mind is an outvac cycle that fit's every lunan's budget. So] the bike must be mostly buildable from local materials with simple tools and basic stock materials; all systems required for it to function as transport must be field repairable. Simplicity. Something a back yard mechanic can build and repair – exclusive of the electronics, of course – but there should be no electronics that are absolutely required for the bike to operate. Electronics must be something that is bolted on and if necessary unbolted and tossed into a crater to lighten the load...


The minute part of the design requires a special tool or material, my design criteria demands that that element be dis-carded from consideration. Simple. Indigenous. Independent.

Ad Astra! – Dale

Human-Powered Moon Trike

Call for a Technology Demo for ISDC 1998 – Milwaukee

One of the more ambitious goals outlined in the plan for ISDC '98 – Milwaukee is to present a number of low budget [\$100-\$5,000) technology demonstrations of tidbits of technology that will be needed, or useful on the space frontier, and which should not take that much money to demonstrate.

A human-powered Moon Trike is such a possibility. Because gravity is only 1/6th Earth-normal, but momentum remains full Earth-normal, to prevent tipping, the vehicle should have a very wide track, wheels that lean into turns, and a low center of gravity (hence a recumbent rider position seems ideal). Any interested group should attempt to find its own industrial and corporate sponsors, advisors, project managers etc. and register their effort with ISDC '98 – Milwaukee, P.O. Box 2102, Milwaukee WI 53201 which will attempt to provide advice and assistance. 

Commercial Moonbase Brainstorming Workshop

COMMERCIAL MOONBASE BRAINSTORMING WORKSOP

Report by Peter Kokh, First Contact II Co-chair

On October 7th, 1995, at a Science/Science Fiction Convention in Milwaukee called **First Contact II**, LRS hosted a 3 hour brainstorming workshop on the "Design Requirements for a Commercial Moon Base." The Lunar Reclamation Society (NSS-Milwaukee) and Milwaukee Science Fiction Services are joint partners in this new hybrid convention. Leading the workshop was the special LRS "Doer" Guest of Honor, **Greg Bennett**, CEO of The Lunar Resources Company in Houston, and chief architect of "The Artemis Project"™. Co directing the session were Mark Kaehny and Peter Kokh of LRS. David Burkhead of Spacecub fame also participated. There were eleven of us altogether.

After a few general remarks about what we were going to attempt to do, **identify things a first lunar outpost could do to make money**, we broke up into two brainstorming groups (larger groups are unwieldy).

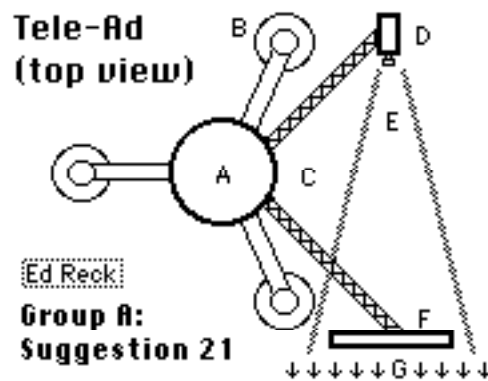


Group A: Greg Bennett, Mark Kaehny (group secretary), David Burkhead, Edwin Reck, and Mark Roth/Whitworth — came up with the suggestions below.

=>The numbering reflects only the order in which the suggestion was made – given the limited time, there was no attempt to put these ideas in a logical order, much less to come up with them in a logical order – brainstorming, by its very nature, has to be free-ranging and unfettered. The inevitable chaff can be separated out from the wheat later. The dynamics of group brainstorming is such that an idea presented “half-baked” by one person, can then be “fully baked” by others in the group. It is an exciting process.

=> The contents in square brackets, [], are added by the MMM editor, a non-participant in Group A, and may or may not accurately qualify or reflect the intent of the suggestor.

1. (a) CD-ROM “Artemis Story,” (b) full video interactive 3-D animation videotape with celebrity speakers. – [from Ed Reck]
2. **Sell rides on training equipment** similar to Rand Simberg’s Space Lines. Actual training.
3. **Photo CD-ROMs pictures.** Documented Travelogs, National Geographic style.
4. An **online WWW pay-for-data site.**
5. **Animé – Japanese Animation – CD-ROM**, magazine story.
6. **Licensing the Setting i.e. of “the Artemis Universe”** (6a) Creating “Artemis” Product Lines – Children’s toys.
7. **Scientific sponsorship** – rack space and crew time, paid for by corporations as good will advertising
8. **Hardware junkie big name contacts** – Bill Gates?
9. **Flight Models** – Estes type static models and mockups [for sale to theme parks, air and space museums etc.]
10. **Babylon 5 newsgroups** – meet people – Staszynski etc.
11. **Sell Lunar Samples, Made on Moon scientific novelties**
12. **Sell [lunar regolith] simulants and scientific novelties**
13. **Television Story** – Shows on all possible variations on “nationality of the Moon”
14. **Solar Power Demonstration** – small power satellite
15. **“Save the Earth”** – sell concern for Earth’s future
16. **Sponsoring Conferences** – make money off of fame, leverage off fame (credibility problems?)
17. **Sponsorship of Companies** – “Proud Sponsor of ...”
18. **Sell bricks made from lunar regolith simulant**
19. (a) **Selling place names on the Moon** [of small features to be named after donor etc.] (b) Selling burial plots on Moon [for lightweight cremation ashes.]
20. **Long term storage in cold rad-sheltered vacuum:** sperm and egg bank; biological and pathogen samples; archival space for data and knowledge stored on magnetic media; etc.
21. (a) **Robotic Probe** – B/W 10 frames/sec. [illustration below]



KEY: A. Lander core with power and communications package; B. One of three landing pads; C. retractable booms; D. videocam; E. Videocam’s field of view;

F. Electronic message board tele-changed from Earth; G. Background scenery.

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

21. (b) **Signs on the Moon whose message can be telechanged from Earth**, with image of sign in lunar setting transmitted to Earth – i.e. real time unobtrusive advertising on the Moon.
22. **High Definition digital video** [the Artemis Story, etc.]
23. **TV produced on Moon.** Aerobics, Kick Boxing and Karate, [and the obvious bootleg videos which must remain rumored.]
24. **Selling 1/6th g rides on counterweighted gym sets** [such as the Mars-grav weight compensating gym set made by Ann Arbor Space Society]
25. **Sports Programs** [uniquely lunar sports that do not need a lot of pressurized volume – with fast, neat action and high spectator value – direct pay-for-view broadcasting to Earth]
26. **Maps of Moonbase area** [wall murals, placemats, anyone?]
27. **Models: static and working**
28. **[Merchandising mail order] Catalog of cool space stuff**
29. **Pay to work schemes** [like architectural and paleontological "digs"] Hands on patronage. Field Trips. Sponsored trips [can be to terrestrial sites where neat preparation and simulation things are happening]
30. A **newsletter "Holidays on the Moon"** published when morning comes to the proposed settlement site [i.e. moonthly]
31. **Medallions** – [individualized] matching set – one sent to the Moon. You keep the other one.
32. **Mission Control Center for the Artemis landing missions to be located in a Theme Park** [pay-to-observe]
33. **Coin-operated games**; your face in a cool Moonbase setting
34. **Limited Edition Prints**, signed by artists, countersigned by the 1st return crew, e.g. famed artists like Kim Poor
35. **Mural Pictures** [Murals are scenic wall papers 4 large pieces across the top and 4 across the bottom, not pre-pasted. Environmental Graphics of the Twin Cities is top manufacturer of nearly 2 dozen scenes which sell for \$40–50 and include Earth over Apollo 17 landing site, Columbia in orbit over cloud-studded Earth, and Saturn and its moons]
36. **Space-wear and Moon-wear** clothing for Ken, Barbie dolls.



Group B: Peter Kokh (group secretary), Fred Oesau, David Crawford, Doug Seitz, Jim Plaxco, and Kevin Crowley.

=> Whereas Group A concentrated (not exclusively) on money generating ideas to get the Artemis Project "on the way," Group B chose to concentrate (again not exclusively) on money generating ideas that would apply "once a permanent occupiable outpost was set up."

1. **Testing/tending** of prototype feasibility demonstration **equipment** for mining operations, beneficiation processes, other processing: e.g. lunar oxygen production, silane [silicon-based analog of methane] fuel production; iron fine extraction and sintered iron product manufacturing; i.e. Artemis crew-members serve as time-share mission specialists for companies hoping to do industrial business on the Moon.

Money would be earned not only from providing time-share trained labor. Income would also be generated by carrying along equipment to the Moon, shipping back various processed and manufactured samples, etc. i.e. renting payload space and mass aboard the Lunar Transfer Vehicle, and descent/ ascent vehicles.

2. **On site Advertising.** More elaborate possibilities than in # 21 above because of the availability of crew for non-electronic changeouts, as well as part time models, actors, etc. The availability of crew also permits greater latitude in changing the all-important background setting, i.e. in total picture composition. It allows moving "commercials" as well.

3. **Setting up and Tending Telescopes** and other astronomical installations (changeout of instrumentation) for university-consortia etc. This would involve trained time share crew as mission specialists, and fees for payload bay space and weight as in # 1, above.

4. **Teleoperated "Working" Robot-Rovers** – Artemis sells **minutes/hours** for the right to teleoperate mobile equipment that (a) emplaces regolith shielding over the habitat complex; (b) grades approaches and aprons, improved landing pad, etc.; (c) collects dust and rocket samples.

Time could be purchased directly, or, seeing that it would be expensive and eliminate all but the best-heeled of individuals, corporate sponsors (or Artemis itself) could raffle off the right to teleoperate such equipment, after a minimum number of hours of simulation training, of course, this included in the package, so that the actual time would be well spent, both to reward the lucky individual teleoperator, and to maximize for Artemis the efficiency and safety with which the needed work gets done.

This concept would not be unlike going on a paid "teleoperated" archeological or paleontological "dig."

5. We **noted** that many income opportunities will presuppose that Artemis planners had picked a **visually exciting site** with its surroundings, not just a scientifically exciting one.

6. **Photograph panoramas** deserving of being rendered as **wall murals** (wallpaper, see #, Group A, above). This will include one of the Artemis Moonbase itself, either/both as under construction or/and as completed (phase 1), as well as various untransformed scenic vistas in the area.

Some of these murals could be available for open reproduction, others sold in limited sets of 100 to generate high individual auction/bid prices.

7. **Telerobotic lessons** sold separately to qualify winners of teleoperation time. See # 4, above.

8. **\$100 million lottery** – winner to be trained as time-share mission specialist along on the first, or second mission.

9. **Teleoperable manufacturing equipment** to be engineered by rival competing engineering teams pro bono – the carrot reward being the right to get a percentage return or royalty on income generated by the teleoperated device for the its operational lifetime.

10. **Entertainment pay-per-view TV produced on site**, capitalizing on eerie effects of 1/6th gravity: one or two person ballet performances (doable on a small set); midget sumo wrestling (our apologies to the Little People or those of Japanese descent to whom our fun suggestion is offensive); once a bigger "gym" is available, Lunar Jai Alai.

11. **Made, or hand-selected on Moon artifacts**, coins, jewelry. Cut and polished breccia broaches or ring stones. Sintered iron coins to be polymer coated against rust on arrival on Earth. Items made of glass spherules. Necklace glass capsules half-filled with common regolith Moon dust.

Weightier and thus much more expensive: sinter-cast block which bears your own footprints, made on the Moon with a casting or your very own foot/feet or shoe(s)/boot(s). Sinter-cast blocks with custom valentine-type message.

12. **Selling Names:** of modules and parts of modules of the outpost and lunar descent vehicle. e.g. the John Doe porthole, the Jane Doe Hall (meetings, TV studio, dance hall, gym, Jai Alai court, etc. etc. multi-use larger volume hard hull module or inflatable.

Also getting corporations to pay for additional mods or upgraded interiors of planned modules – all for the ad value = e.g. "furnished by Apollo interiors, of city, state."

13. **Repository for cremation ashes.** This can be under the open star-spangled sky, UV-protected by a quartz pane.

14. **Biological Quarantine Facility** for sample all-but-extinct pathogens and toxins too dangerous to be kept indefinitely at the Contagious Disease Control Center in Atlanta. An associated lab could be a follow-on.

15. **3D computer-controlled variable mold stamping** device which will render your footprints/handprints and a photo of same on the Moon, in an area to be set aside not ever to be re-disturbed . Different from # 11 (second paragraph) above.

16. **Lunar Spaceport Beacon** which can flash messages (commercial ad or personal [monitored] for a high fee) in Morse code when visible from Earth during local Moonbase nightspan. [see MMM # 89, OCT '95, page 1 bottom]

17. Along the same line, experiments in local nightspan **fireworks and light shows** to be paid for by sponsors on Earth for very large terrestrial audiences on special occasions.

18. Afterthought on # 11 **jewelry** ideas above. For necklaces, glass spheres with actual lunar vacuum (glass is stronger under compression)

19. **Actual Signatures on the Moon:** Artemis would sell the right (and small space) to write/engrave your signature on various pieces of structural or operating hardware(a) to land temporarily on the Moon = cheaper, or (b) be part of the perm-anent outpost installation. This idea is attractive because it does not add to the weight or cost of the hardware to be landed on the Moon. A much less expensive option (c) would be to take along your signature in microfiche or electronic form.

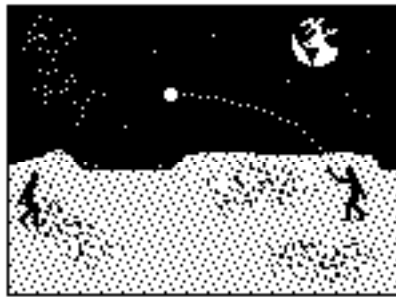
Reflections on the Workshop

As I had guaranteed Greg Bennett as we were about to start, this process was sure to come up with many ideas that have already been thought of in previous Artemis Project brainstorming sessions, but also certain to come up with some new ideas previous groups had not thought of, or at least new variations. Afterwards, Greg assured me that the Workshop had delivered as promised. All participants found the exercise very stimulating and the high point of their convention.

In Houston and in Huntsville, the ideas outlined above will be merged with the results of previous marketing and income generating brainstorm sessions. ###

MMM #92 – February 1996

WORDSMITH CHALLENGE # 1



Calling all wordsmiths! We need to coin a word.

Here on Earth, we throw a ball “into the air.” You could do and say the same on Mars. But what about on the Moon? No air! And to say you threw it into space or into the vacuum or into the void would be ambiguous, if not misleading. These words refer not to the boundary volume just above the surface (as does “air”) but to the endless emptiness that goes on and on, up and out.

Send your suggestions to the MMM submission address (not the LRS PO Box) or to KokhMMM@aol.com and, to the person whose suggestion we like best, in addition to 15 minutes of Warholian fame, we will send a copy of the Collected Major Articles from MMM, issues # 1–20.

Feedback from Readers

Name the boundary layer vacuum over the lunar surface.

Suggestions: “**the overland**” – “**the nary**” – “**the vac**”

=> **Dorothy Diehl** <AstraDiehl@aol.com> “In the C.S. Lewis book, The Silver Chair, many of the inhabitants live under-ground. They call the place where they live the “Underworld.” The place where others live on the surface, they call that the “Overworld.” We could call that area of space directly above the surface of the Moon the “lunar **overland**.” When we have vacuum tube trains or low altitude rocketed flying vehicles, we could call them “lunar overland vehicles” or the Lunar Overland Express.”

=> EDITOR: to me, overland connotes “on” the surface rather than “over” the surface, and so doesn’t fill the bill. But thanks.

=> **Garth A. Becker** <103323.2665@compuserve.com> "Why do you want to coin a new word keep it simple .. just say "up" and "down." The more specialized you make the lexicon the less people will want to learn and follow us."

=> EDITOR: Many of the worlds several hundred languages have only a couple of thousand words. Many have no technical vocabulary at all and you cannot get even a high school education in them, let alone a college degree – no textbooks. First class languages like French, German, Russian, Spanish have highly developed vocabularies of 100–200,000 words. English, however, has 650,000 words. It is no coincidence that English is the closest thing to a world language we have ever known. It got that way coining, adopting, or borrowing new words for new things and ideas – not by continuing to rely on existing words. Stop and think how many of the words you use would be unintelligible to Abe Lincoln or Daniel Webster. Fuselage, Carburetor, spark plug, trajectory, kleenex, shampoo, TV, videocam, jack, dead bolt, junk bonds, velcro, romex, vinyl, liftoff, dashboard, goalie etc. etc. Try to talk about any of these without using those words and using only words Lincoln knew. Then, get back to me if you honestly think that what you have come up with has made language "simpler." If we stop coining words, thinking to keep it simple by using ever longer and longer phrases, language will get more complex, not less. The problem I outlined was an aspect of the lunar environment that will be an "everyday" thing to people living there. They have the right to use a simple word rather than a phrase or acronym, or a word that means something else.

=> **Nelson Thompson** <nathompson@iwl.net> "One simple solution would be the word 'nair' – short for 'no air.' However, that's a bit clumsy and could be misunderstood. Then I remembered a seldom used word, a 'Southernism' actually, that I heard in my youth: nary. It meant 'not any.' As in, "I heard nary a bad word about him all my life." It's short, simple, not likely to be confused with other words, and has (had) a colloquial meaning not too different from what you wanted. The vacuum of space, even at the surface of the Moon, is literally 'not any.' So I suggest **"the nary."**

=> EDITOR: Runner up winning suggestion! Thanks

=> **Thomas Heidel**, Milwaukee WI – In MMM you regularly speak of the lunar surface as the "out-vac," a coinage probably modeled on the Australian "outback." In consonance with this I suggest simply **"the vac."**

=> EDITOR: I like it! Grand prize front runner to date. PK



Pioneer HOLIDAYS
PIONEER HOLIDAYS and other festivities
By Peter Kokh

While "new traditions" (as oxymoronic as it sounds) are being made all the time, there is little doubt that those that command our observance most deeply are those which are oldest, rooted in our collective gitgo times. So it is with Holidays: Christmas, Easter, New Years go back millennia (two at least). Thanksgiving goes back nearly four centuries. The 4th of July will be 220 years old next time around.

We can expect that as the lunar frontier becomes fully established with the coming of age of the first native born generation of Lunans, the holidays and festivals they will most cherish will include those observed by those establishing the first beachhead.

The Apollo 11 landing (July 20th) is sure to be observed, as is the "infamous" day of retreat, the liftoff of the Apollo 17 crew (December 10th). But neither of these "trivia" dates will rival the enthused celebration of the **"Day of the Return"** when humans come back to the Moon intent on setting up an open-ended "permanent" presence leading to genuine settlement.

The first crew may only set up camp and then return to Earth, to be followed by the first crew intent on staying a full day-night cycle (the lunar "sunth") or more. So closely connected with the observance of the Day of the Return will be the celebration of that first successful "overnighting" and the greeting of that first "sunrise" – **"First Night's End."**

Finally, “**Ever Since Day**” will mark commencement of uninterrupted human presence on the Moon. If I were to put a friendly wager on which of these will be the most honored in Lunan settlement tradition, it would be on “First Night’s End.” There will be a special flavor to this holiday, the shared mutual congratulations at having survived this “initiation” imposed by the Moon itself. And for all non-native born Lunans, there will be a special personal resonance with memories of their very own “First Night” and “First Night’s End.”

Other history-rooted anniversaries may mark the birth of the **first native born** Lunan. And later, the first native born grandchild (i.e. second generation, whose health will be the final test of whether or not humans can stay on the Moon indefinitely) [See MMM # 47 JUL ‘91, p. 5 “Native Born”]

Not all Lunan Holidays and festivities will take root in such historic occurrences. Some are sure to be bound up with the **Moon’s natural rhythms**, much as a growing minority of us terrestrials observe the equinoxes and solstices. Local **sunset** and local **sunrise** will be big deals, something to mark with a special meal or wine or friends – simply because they occur on a 28+ day cycle, not a 24 hour one.

If a particularly appropriate **Lunan Calendar** is adopted [see MMM # 7 JUL ‘87, “Moon Calendar” – republished in MMM Classics #1], with “sunths” of 28.5 (24 hr.) days instead of 30.5 day calendar months, with the discrepancy with Earth reckoning made up with occasional “leap” (“intercalary”) “sunths” or weeks, Lunar New Years may only approximate the fall of New Years on Earth.

In such a case, the observance of religious feasts and holy days may also vary with that on Earth, without spiritual harm to those who honor them. This will be much to the chagrin and resistance of religious fundamentalists (those who give major importance to the minor, and minor importance to what really matters, and call every one else heretic and infidel.)


Solar Eclipses on the Moon are the flip side of Lunar Eclipses on Earth. They will be much more of an experience for Lunan pioneers and settlers than any eclipse on Earth (even total Solar). They will last several hours locally, and possibly may occasion the morning or afternoon “off” (work or school) as the case may be. And it will be the most favorable time for looking for city lights on Earth’s nighttime face.

In time, other “**political**” **milestones** will come to be honored in settlement tradition – the day when home rule is won, or independence declared, for example.

Historic and festive holidays will not be the only early-rooted traditions. **Pioneering songs and ballads**, even candidate settlement **anthems**, are sure to be written, sung, performed, and loved.

There may arise too special **festive foods** with historic significance. We have pretzels and cross-over buns associated with Lent, unleavened bread associated with Passover. Eggnog, Christmas cookies, Easter Eggs, Pumpkin Pie are among many foods especially popular at specific festive times. On the Moon, many long-loved foods and recipe delights will not be available early on. Special early frontier substitute food and menu items, beverages too, even if in time the need to make such substitutions eases, may be prepared and consumed with relish on commemorative occasions. Associated with such holiday tradition meals may be time-revered toasts, blessings, and mutual greetings.

Certain **plants** are associated with various observances on Earth; poinsettias and mistletoe with Christmas, for example. And plants grown successfully in the early outpost days may come to be associated with various Lunan observances in like fashion.

The first humans to return to the Moon may think that all they are doing is erecting, deploying, setting up, demonstrating, testing, etc. But even the little incidental things they do, may in time take on special meaning and color not at all obvious at first, to become ritually repeated. This will all occur sometimes spontaneously, other times with alertness, if not deliberateness, as a part of fulfilling the very human need to impose on nature’s own rhythms, a festive and commemorative **cultural rhythm** of our own. Such cultural rhythms are a major element of the **social glue** that binds generations together. In this way they will bind future Lunan generations, much as similar traditions have always served in terrestrial communities throughout the globe, and throughout historic and prehistoric times. 

who  will  pioneer?

WHO WILL PIONEER: Leaving the familiar lush green hills of Earth for the Magnificent Desolation of the Moon for an open-ended stay won't appeal to many

By Peter Kokh

Space. Alien planets. As it starts to get real, it will also start to slowly dawn on media sci-fi-nurtured enthusiasts that the real thing is much less “nifty,” “neat,” “futuristic,” “utopian” etc., than imagined. The frontier will be a rough, hard place with few creature comforts, few opportunities for self-indulgence. We won't be stumbling on new aliens every week, indeed, perhaps never. Nor will we be visiting shining exotic cities.

Space, real space, offers little non-economic perks beyond one: the chance to start over, to start fresh, to have a hand in shaping the roots of a raw new community. Many immigrants came to America, Canada, and Australia with visions of making great wealth, and indeed some have done so. But many more came motivated by the lure of freedom. At first this conjures up images of political or religious oppression in the “old country,” but as proud as we may be of our political and religious freedoms, I suggest that this is only one type of liberty. Many more down to earth pragmatic people may have been drawn to our shores in search of another freedom altogether. Cultural freedom. Freedom from civilizations in which almost every aspect of life is stiflingly set. The freedom to start over. The opportunity to have a hand in shaping a new way of life.

When it comes to space and the call goes out for would be pioneers, not to go on some exotic mission, but to leave Earth behind, perhaps never to return, it is not those in search of the excitement that Science Fiction visions promise who will respond. It will be those for whom the futuristic, the ultramodern, the high tech, the super-sophisticated, the exotic, etc. means little. Those vulnerable to such turn-ons are best advised to stay on Earth, even as their spiritual ancestors stayed in genteel sophisticated Baltimore and other eastern cities instead of following Horace Greeley west.

Those first in line to volunteer will be those for whom the pleasures and gratifications of Old Earth have long become empty, for whom terrestrial creature comforts weigh less than the opportunity to roll up the sleeves and get the nails dirty building a raw new world up from scratch. Those who seek mainly to “consume” the “new,” will stay home. It is those whose bell is rung by the satisfaction of making very real personal “contributions” to an untamed infant world, to help polish the rough edges of this frontier one by one – it is these who will apply.

It will be tempting for governments, multinational companies, and other major players involved in opening the frontier to exercise a high degree of a priori control over who gets to go. Planners will say we need so many engineers, so many architects, so many workers. They will attempt to screen for personality problems. The temptation to “micromanage” who gets to go will be enormous. The need to micromanage will have many impassioned defenders.

But it is not the only way to go, nor is it consonant with the best in our own time-honored traditions of individual self-selection. It can be argued that “we” can't just let “anyone” who imagines space or the Moon or Mars is for him or her to go – we'd get too many unsuitable people: antisocial types, alcoholics and addicts, criminals, psychopaths, “God knows what.” But there is another way to let personal freedom rule and still not end up burdened with a lot of unsuitable people putting a drag on struggling frontier settlement communities.

That way is to make sure that “self-selection” is “informed” self-selection. The public in general must be disabused of Sci-Fi-fed misconceptions about space. The dangers, the risks, the lack of creature comforts, the sacrifices and hardships, the substitutions and the do-withouts, the hard work, the isolation, etc. must all be drummed in over and over. That for every person willing to pioneer Antarctica you could problem find many thousands willing to pioneer Mars, a much less friendly place, is eloquent testimony to endemic mass misconceptions.

One public perceptions are corrected, replaced with the much harsher reality, far fewer people will be so eager to volunteer for the frontier. But those who do, all these reality checks notwithstanding, are far more likely to have the “right stuff” than any group carefully selected by micro-managers out of a flood of unenlightened mis-enthused volunteers. What we need is a philosophy, then a policy of “educated self-selection.”

This said, can we predict who will be more likely to volunteer, to have the “right stuff”? Much will depend on the life experience of the prospective volunteer. Climate, Culture, Education can all predispose on the “environment” side, irrespective of genetic or inherited personal qualifications.

Those from hardier climes

Obviously, those already happily adapted to hardier terrestrial climes will find life on the Moon or Mars far less depressing than those addicted to life in Earth’s more idyllic and comfortable climatic oases. So it would not be surprising if among the “informed self-selected” settlement and frontier applicants we will find an above average representation of arctic, subarctic, north temperate dwellers, as well as desert peoples. We might expect them in general to be hardier, less deluded with expectations of paradise.

That means Alaskans and Canadians and Snowbelters and Scandinavians and Icelanders and Siberians and Eskimos and Patagonians and Falkland Islanders, etc. There are also temperate and tropic mountainous areas where life is challenged. Such places too may nourish the “right stuff.”

While there will be some sunshine oasis people, it would not be surprising if their ranks made up the bulk of disillusioned returnees to Earth. The Frontier will be rough. No offense to all you readers in California, the desert Southwest, Florida, and elsewhere where the “good life” is easy – but if you would shudder about a job-relocation to Wisconsin or Minnesota, perhaps you had better take an honest introspective hard look and think twice about early frontier space locations. And if you were born and raised in a hardier clime but have made a “life-style-motivated” relocation to a place where life is undeniably easier and more comfortable, an honest session of introspection may suggest that you confine your participation and support of the movement into space to what you can do from “Couch Earth.” It will be a while, a very long while, before hardier folk have succeeded in building cushy utopian O’Neillian human zoo parks in free space. Once pioneering types seeking only the satisfaction of helping “start over, start fresh” have paved the way, and it safe for you to leave the womb world without danger of breaking a nail, we’ll let you know. Meanwhile marsupial type “Joeys” will find themselves more content closer to the pouch.

Cultural push and pull

The search for a place and conditions in which one can “start over” go hand in hand with the need to get away from a place in which one’s incentive and self-expression and opportunity to make a meaningful contribution are stifled. Those tired of paternalism, of over-direction, of suppression of initiative and resourcefulness; those unable to compete in a world where all the prize positions are already taken; those tired of too many arbitrary micromanaging rules; those ready to question the status quo and the given – among such will the spark of a dream to start fresh take hold, and overpower the hardships and sacrifices ahead. People who see no future where they are, are more likelier to see an acceptable open future where others, content with their present circumstances, would dread to go.

And then there are those who simply badly need the shot in the arm that only a major life change can bring: a new job amongst new fellows in a new place, without most of the rules set by people long since dead. People who’ve lived “one life” and are ready to start all over, fresh, where most all positions are open, where the future is less restricted, will appreciate the hard-won far-between rewards of pioneering. Space is a universe of places in which to start over, start fresh, start forgiven.

This country and others like it (Canada, Australia, New Zealand) were built by people leaving places they where they had never been able to “fit in.” Those that did “fit in” stayed in the old country. Blessed are the second best, for the same is true of individual plant and animal colonies pioneering new niches. What didn’t fit in in the old venue, works just fine in the new one.

Yet baggage happens. Some are “misfit” not just in reference to arbitrary stuffy sedentary cultures, but by any sense of the term. The problem is not with their surroundings, but with themselves. Some of those wanting to get away and start over, will prove to be just as out of stride on the frontier. Again, informed self-selection will tend to weed them out. But that is a separate problem.

The Melting Pot

Born before Pearl Harbor, I belong to a generation that was proud of America’s “melting pot” heritage, and abhor association with advocates of immigration damage control or even outright ethnic cleansing. Yet there are many space enthusiasts out there who in the closets of their hearts see the space frontier as a place to start fresh “free of” ethnic “undesirables.” Whether in groups, those so inclined will ever be able to put up enough money to collectively realize such a vision is questionable. It can hardly be argued that the more diverse the gene pool, the healthier and more creative and produc-

tive can be the resultant civilization. Those willing to pioneer the frontier and possessing the “right stuff” will come from all over. It is likely that to the extent multinational government and/or business consortia are involved with the opening of the frontier, that it will begin, and remain a genetically open one.

What all pioneers will have in common – a vastly new, untested, and challenging frontier – will be much more intensely felt and immediate than any of the national, cultural, or ethnic culture traps which worked to keep them apart before. The more quickly a new frontier culture arises and the more depth it has, the easier it will be to forget the past cultural roots and immerse oneself in the new.

Talent, cultivated skills, and training

Being hardy and being driven to trade the comfortable old for the hard-going new, will not be enough to land anyone a spot on the front lines of the space frontier. You can’t drive to the Moon in your Ford, nor fly there in your Cessna – let alone saddle up the old mount or hitch a ride in a covered wagon or stage coach. It will take a small fortune to go, and for most that means finding a frontier-based employer willing to pay one’s fare.

Self-selection will have to be active, not passive. One will aggressively have to seek training and education, perhaps in multiple fields, if one is to have any hope of fielding a winning resume. People with double, triple qualifications in needed fields will have the edge, not just to be able to pinch hit in emergency, but able to do double duty from the start. For on a frontier, there are always more things needing to be done than there are people to do them. An outpost with a dozen people, may have two dozen jobs needing to be done. And it will be that way for a long, long time.

The frontier will need more than technical skills in manufacturing, mining, construction, engineering, etc. For morale’s sake it is important to humanize an alien location as soon as and as pervasively as possible. Pioneers with artistic or craftsman talent, singers, musicians, dancers, comedians etc. able to forge a new frontier appropriate culture. It will be a long time before the frontier can afford to import dedicated artists and performers. What is needed is the person who can do the technical job during the day, and fill the artistic and entertainment function after hours. So get a double masters with on-the-job double experience, and hone those creative talents too boot, and you’ll have a great chance.

To the prospective employer, experience is a seller. People with a record of successful problem solving, finding new pathways to get a job done will have a leg up. Those who accept without complaint the challenge to adapt, substitute, make do, improvise, invent, and otherwise demonstrate strong resourcefulness, will be especially impressive.

The frontier will require both leaders and followers. But it will especially need the “self-led,” the self-driven, the self-motivated. Indeed, self-selection starts here. One not only has to “want to go.” One has to want that “aggressively.”

Yet, an element of luck will always remain. One has to be in the right place, and at the right time. For many of us, no matter how high we score in the “right stuff” department, time will prove our enemy. The frontier will not open soon enough. PMPM



Permanence has to be earned, not proclaimed

PERMANENT OUTPOST By Peter Kokh

“Permanent!” You would think its is a cut and dried word. But like all adjectives, its denotation can be justified in degrees. Sure, it’s not at all what we mean when we use the term with reference to our presence on the Moon, but in a sense our presence is already permanent. Even if we never return, indeed especially if we never return, the Apollo astronauts will have left a relatively “permanent” human presence on the Moon. Their bootprints, tire tracks, and assorted left behind equipment and paraphernalia [lunar museum hope chest] should outlast all of us individually, outlast, indeed the most long-

lived of the current family of terrestrial nations. It will simply take that long for the process of micrometeorite rain to “garden” the surface at the landing sites to remove all traces.

But that’s not what we mean. The Apollo crews were just on “scientific picnics,” our happy campers taking their lunar module “tents” with them when they lifted off. The next “small step, giant leap” (to use the slogan of the upcoming New York International Space Development Conference – you all come, now!) is for the next returning crew to leave behind a habitable structure, protected from the elements by a blanket of moon dust (regolith) shielding. That goes much further to merit the description “permanent presence.”

Let’s quibble no more. What we all mean, want, is to plunge into a new era, one in which from that day forward, there will never again be a sunset on a moon without humans working and living there somewhere. For the more easily satisfied, the less expectant, that means no crew will ever return to Earth without first being replaced.

But to the rest of us, this is a wooden nickel. What we mean, want, by “permanent presence” is real settlement communities in which a significant part of the population has come to (and someday been born on) the Moon fully intending to live out their lives there, raising families, having children, working for their livelihood, and doing the whole spectrum of human things we call living. Now, in that sense of the term, we are talking about an era of much more ambitious activity on the Moon than are those folks happy to have an Antarctic style government/science outpost with rotating crews.

Our point in this essay is that we can’t get to this higher realization of the term “permanent” from day one of our return with a habitat module, without the right set of plans, without the right official (government, multi-national industry, or private undertaking — i.e. the chief responsible party in charge) “philosophy.”

Philosophy, shunned as irrelevant or useless by self-styled pragmatists, is, whether its principles are sound or loony, the most powerful force on Earth. Everyone operates with an implicit philosophy, even criminals and misfits. As hard to pin down as it may be, as difficult to agree upon as we know it is, is still the ultimate fuel that powers and drives (steers) everything in human activity and history. So it is worth paying attention to, worth trying to get it right, appropriate, and productive of results.

We must sell, and buy, “the ladder” of permanent presence on the Moon, as such — as the whole ladder. **It has been, is, and forever will be, a failure-guaranteeing philosophy to attempt to neutralize potential opposition by selling the dream one seemingly innocuous rung at a time.**

Why? When we do so, **the rung gets designed by a committee with many of the players oblivious of the nature of the rung to serve as a step to another rung**, and on and on. Look at our recent past. First, not to alarm anyone, we sold the idea of a space shuttle. That in place we introduced the idea of a space station. That now seeming to finally have a momentum of its own that will lead to its at-long-last realization, many of us are beginning to agitate for a return to the Moon and a first expedition to Mars.

The trouble is, the space shuttle we ended up getting was designed by a committee many of whom did not consider the need to maximize its design so it could best serve as a shuttle to a station. Repeating our mistake, the station, in each of its design iterations, has again been designed by a committee, most of whom have not considered it important to maximize the station as a platform whose primary function is to serve as a springboard for deep space missions beyond LEO and GEO to the Moon, to Mars, to the asteroids.


And so we have an ultra expensive shuttle with which we have to make do, and will get an even more expensive station downward looking in design and function (an easier sell to those to whom we were too timid to close the real ladder).

If we follow suite, the first lunar outpost will be an end all in itself, poorly designed for expansion, or to support the kind of ambitious experimentations and demonstrations needed to properly design expansion phases. If we do sell the outpost, once again it will become **“a self-halting step forward.”** We will indeed have gained only an inadequate high tech shelter that will be abandoned at the next budget crisis. So much for “permanence” – a permanent “ghost townlet,” eventual “ruin.”

That’s why it is difficult to see the sense of political space activism, aimed at programs rather than at legislative facilitation. **“The political process by its very nature cannot produce anything intelligent.”**

A commercial, industrial undertaking has much more of a chance, even with myopic MBAs running the show. A for profit enterprise or multinational is far more likely to design and plan in a way that leads to growth – and real permanence. Who has the deepest pockets is an irrelevant consideration. Rather the question is who has the drive, the persistence, the absolute need to succeed?

“A government operation would put primary stress on science while doing token experimentation in the practical arena of learning to live off the lunar land. It will have saved money up front, and the resulting “mule station” will indeed be sterile, in no way pregnant with the future.”

So agitate not for a “permanent outpost.” See to it instead that legislative and treaty roadblocks are removed, that economic incentives are in place. Then we will get a town built brick by brick, settler by settler for the long haul. Not just a permanent ruin-to-be. 



ISDC 1998 MILWAUKEE

A Space Frontier **Tech Demo** Program – **IDEAS** for Lo-budget, 2 yr.– feasible demonstrations of technology items that will be needed or useful on the **Lunar Frontier**.

[The following suggestions by no means exhaust the possibilities and readers are encouraged to think of, pre-brainstorm, and report to MMM of other neat doable projects that will help bring home to all of us, veteran space enthusiasts and general public alike, the concrete doability of space pioneering on the Moon, Mars, and elsewhere in the Inner Solar System.]

  **Moon human-powered Trike**

See MMM # 91, DEC '95, page 9, column 2.

  **Silane Producing Sebatiar Reactor**

Silane, SiH₄, is a fairly high energy liquid silicon analog of methane. Combining Moon-scarce hydrogen with Moon-abundant silicon in this way, extends the payload lifting power of hydrogen by six times. Silane is a top candidate lunar-appropriate rocket fuel for suborbital hoppers and Earth-Moon ferries, and lunar surface to orbit shuttles.

Silane could also be burned with lunar oxygen in an internal combustion cycle engine for lunar surface vehicles and electric generators for use at nighttime.

DESIGN, BUILD, and DEBUG a silane producing sebatiar reactor. DEMO for ISDC '98 Milwaukee.

  **Silane Internal Combustion Engine**



DESIGN, BUILD, and TEST an engine to burn silane and bottled oxygen in an internal combustion cycle rather than in a rocket motor cycle. DEMO for ISDC '98 Milwaukee.

  **Moon Motortrike**

DESIGN, BUILD, and TEST a motortrike chassis to use a silane burning internal combustion engine. Trike should have wide track, wheels that lean into turns, and low center of gravity, along with 1 ft. minimum clearance. Possibly recumbent rider position. DEMO for ISDC '98 Milwaukee.

  **Atlasmobile**

Assuming the availability of the same silane engine described above, design an “atlasmobile” on the order of the “atlasball” used on American Gladiators™ – a spherical cage moved by a Moon Motortrike or powered cart riding the bottom of a pair of circular tracks. See MMM # 81 DEC '94, page 1.

  **[Rego]’Lith moving Competition**

DESIGN, BUILD, and TEST any of many possible types of teleoperable regolith moving equipment for us in emplacing shielding and grading sites, roads, and landing pads. DEMO for ISDC '98 Milwaukee.

“Turtlesuit” and “Turtlelock”

See MMM # 89 OCT '95 “Dust Control” p. 6.

The goal is not to design a pressurized functional “turtle-back spacesuit” but rather an unpressurized mockup with dummy backpack simply to determine and demonstrate the design factors that will allow its wearer to back up into a conformal turtle lock, effect lock and automatic inner door opening, pull his/her arms out of the suit arms, and reach up through the open back of the suit to be able to reach a grab bar on the inside of the habitat above the open turtle lock door, and thus pull him/herself out of the suit into the habitat.

This project can be broken down into at least two parts: DESIGN, BUILD, and TEST a turtle back backpack and conformal lock port in which the two engage and open together or in tandem, the habitat lock rim engaged with the “turtle-back pack “jamb” on the spacesuit. DEMO for ISDC '98 Milwaukee.

DESIGN, FABRICATE, and TEST, an open-backed suit in which the wearer can extract his/her arms easily from the suit arms and reach up out the back of the open suit. DEMO for ISDC '98 Milwaukee.

1/6th G Sport Simulator

Traditional Earth sports will not translate well to lunar conditions of “sixthweight” wherein everything weighs only a sixth of Earth-normal but retains full Earth-normal mass and momentum. Traction and maneuvering will be difficult. Instead of tragicomic caricatures of familiar sports, we will need games that play with the grain of lunar physical constraints, including small volume pressurized spaces.

DESIGN and TEST a computer simulation program which combines sixthweight gravity with full momentum in which to simulate any number of game and sport plan ideas. DEMO for ISDC '98 Milwaukee.

Lunar in home telescope

DESIGN, BUILD, and TEST an amateur telescope design in which the image gathering components are on the lunar surface, but in which the image is available, without electronic transmission, to the telescope user within his/her pressurized habitat below. DEMO for ISDC '98 Milwaukee.

The game plan:

- Gather a team with the right mix of expertise,
- brainstorm a design
- price the materials and tools that you will need
- make a presentation to potential corporate sponsors

Each Group is responsible for raising its own funds and locating its own corporate sponsors. Some assistance may be available to help transport your device to the '98 ISDC in Milwaukee. The ISDC will endeavor to provide project review.

Any group attempting to put together such a project should register with the Tech Demo Committee, ISDC '98 Milwaukee
P.O. Box 2102, Milwaukee WI, 53208

Further Information:

Peter Kokh (414) 342-0705 eves, weekends
kokhmmm@aol.com ISDC '98 MKE

Alas, none of these concrete demonstration engineering projects were pursued

MMM #94 – April 1996

The Cultural Implications of the Moon's 1/6th G



This month, we return to our essay series on the early days of a permanent human community on the Moon, as we at the **“Lunar Condition,”** the defining set of parameters that go with the territory and will leave an indelible mark on early Lunan culture and civilization. The Moon is a world dramatically different from Earth. One way this was brought home to hundreds of millions was the sight of our astronauts and their moon buggies bounding and bouncing about in the lower gravity. The effects of “sixthweight” will be more than anecdotal. For the impact of the Moon’s environment on pioneers, see below.

The Primitive roots of “Lunan” Culture

This month we return to our series of essays on the very early lunar frontier. It may at first seem that a particularly “Lunan” culture will be a development a long time arriving. On Earth we are used to considerable cultural diversity, both from place to place and through the generations. It may seem outrageous to forecast the day when we will see revealed the considerable family resemblances all terrestrial cultures bear to one another. But there are certain time-and-place-transcending aspects of Earth that insert themselves in every human culture to date. For whatever the differences we love to exaggerate, we all share one very friendly planet, one encradling biosphere, the same gravity, the same protective envelope of sweetened air in which we work and play under wide open blue skies.

The unique equally transcendent wellsprings that will eventually make “Lunan” culture distinctive from all terrestrial cultures, making it in effect the first culture of a new family, will be present from the outset, intensely felt already by the first crew to take the plunge and “overnight” on the Moon.

The Moon is a world dramatically different from Earth. It’s gravity is only one-sixth “normal.” It is without atmosphere of any practical consequence. Its surface lies naked, exposed to the weather of space. It offers no life supporting biosphere of its own. These constraints will make life-as-we-are-used-to-living-it a memory-myth early left behind. As we deal with these facts and their consequences with a swim-or-sink urgency, and as we find successful ways to accommodate them, we will be forthwith face-slapped out of any romantic reveries we may have had. — this month’s topics.

So much for day one! Hardly will we have begun to cope and neutralize these brutalities and two other facts about the Moon will carve nascent Lunan culture even more deeply. The Moon is very dry. And its mineral assets lack some of the industrially strategic elements Earth’s more generous endowment has lulled us into taking for granted. — next month.

We have touched on each of these topics before in sundry articles. We do so again, all in one place, from the eye of the future historian and anthropologist interested in the very early beginnings of what is sure to develop into a uniquely Lunan culture and civilization.

There will, of course be many other things that add color to lunan culture. The sports that arise, for one thing: indoor, middoor, and outvac. Trade relationships and particulars with other off-Earth pockets of humanity throughout the Solar System. Political events. Art and Literature. The performing arts and media. And, of course, the indelible mark of powerful and influential personalities. But all these things will but add flesh to a cultural infrastructure grounded in the physical nature of our host adopted world, the Moon. And this infrastructure will fall into place almost immediately. **MEMO**



Exposed to the Weather of Raw Space

By Peter Kokh

Relevant Readings from Back Issues of MMM

MMM # 5 MAY '87 "Weather" – [MMM Classics #1]

MMM # 37 JUL '90, pp. 4–5 " Ramadas"; "Flare Sheds"; "Solar Fringe Benefits" – [MMM Classics #4]

MMM # 56 JUN '92, p 5 "Naming the Seas of Space – [MMM Classics #6]

Earth and the Moon orbit the Sun together in shared space. Yet their respective surfaces have very different exposures to the elements of cosmic weather. Earth's Van Allen belts and strong magnetic field intercept a major portion of incoming solar flare particles – most of what does get in ends harmlessly in the beautiful displays of the aurora borealis (north) and aurora australis (south). Earth's deeper and wider gravity well attracts the lion's share of the meteoritic material coming our way, yet so much of it burns up harmlessly in the atmosphere leaving a gentle and imperceptible ash dew that the Moon seems unfairly bombarded in comparison. Finally, the oxygen turned ozone in Earth's upper atmosphere filters out the worst of the incoming solar ultraviolet rays. And salted with water vapor and carbon dioxide, the atmosphere serves as an insulator, raising Earth's surface temperatures some 50 °F (28 °C) over the Moon's average surface readings, and helps greatly moderate the swing between extreme highs and lows.

Bereft of both magnetic field and atmosphere, the Moon's surface lies naked, exposed to this many-faceted electromagnetic onslaught. One cannot even compare conditions here with those in low Earth orbit, a realm within the wave-breaking "harbor" wall of Earth's Van Allen belts.

Proper [rego]'lith-shielded habitats, however, offer protection not dissimilar to that of Earth's atmosphere. Both involve blankets. Earth's is gaseous, mostly nitrogen and oxygen. The Moon's blanket is the regolith, the impact-pulverized layer of inorganic 'topsoil' that covers everything to a depth of 2 – 5 meters (~ yards, i.e. 6 – 16 ft.). Pioneers can either find the alternative shelter of a lavatube, or simply tuck themselves under this 'lith blanket. ["lith" is a Greek root meaning stone, here, the inorganic rock-derived powder and impact debris.] Two meters does fine for limited tours of duty. Four meters (13 ft.) would be better for those intending to stay many years and raise families. Both types of blanket stop most all of the incoming radiation and most all of the incoming meteorite bombardment. Both blankets moderate day-night and seasonal temperature swings (the 'lith blanket doing the more effective job, actually.) The similarity goes further. Freeze out the Earth's atmosphere, and the snow of nitrogen and oxygen would leave a powdery blanket of comparable depth.

Unfortunately, the lunan pioneers cannot operate entirely under the shelter of this blanket. In local areas, to be sure, all pressurized habitat, office, school, factory, commerce, farming, and park spaces can be interconnected by pressurized walkways and trafficways – a sort of "mole city." Alternately, a whole local urban complex could be laid out within a spacious lavatube. But intercity or inter-settlement travel would be difficult to manage other than on the blanketed surface itself.

How will Lunans cope given the danger of accumulative exposure to dangerous radiation? A whole spectrum of strategies will be in order. Those whose occupations take them out onto the surface regularly, will wear "rad" bracelets which document cumulative exposure. They will have to rotate surface assignments with duties within shielded environments – under the blanket. When their "rad" bracelets show maximum tolerable exposure, they will be retired to sheltered duties.

Solar flares, however, are one form of exposure that do not come in averaged steady doses. Those caught on the surface during a storm risk fatal nuclear exposure. Regularly traveled routes will need to provide shielded flare sheds at intervals, reachable within an hour or so from the midpoint between them. Excursions to areas without flare sheds may be allowed only outside of flare "season." Solar activity runs in 22 year cycles, fortunately, and this regularity offers a certain assurance of safe travel at most times. Vehicles engaged in emergency excursions during the midst of the flare season?

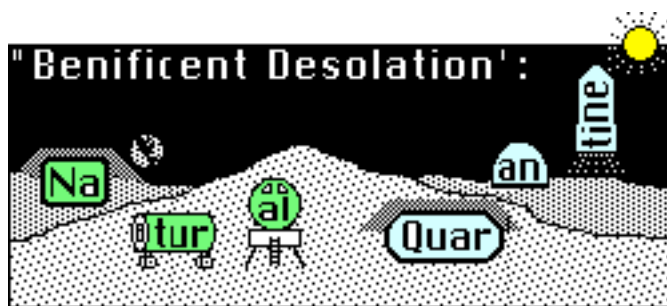
will need to be equipped to “borrow in” on a moment’s notice, or to otherwise erect and blanket a Sun-facing lean-to.

Lunans will learn how to cope with their “weather” just as the folk of Wisconsin and Minnesota and even more extreme climes on Earth have learned to cope with theirs. The populace will quickly acquire a local “common sense” and they will handle it “second nature” style. What to us seems a hostile and alien world, will to them seem cautiously friendly, coaxingly nurturing. It will be no big deal.

There may be consolation prizes to this exposure to the cosmic elements, prizes of economic significance. We can not guess what they are as yet. But even as northerners have learned to make economic hay out of winter, so will Lunans learn to put this naked exposure to good use. And here we are not speaking of the high-level dust-free vacuum over the lunar surface, of certain industrial value. We are speaking of the infall of cosmic rays, ultraviolet radiation, micrometeorite bombardment, and solar flares. Surely, with enough imagination and experiment, industrial and even art and craft processes can be devised to use such exposure as a special tool.

We have suggested that a settlement’s water reserves be circulated on the surface under UV-transparent quartz panes: UV exposure should kill any bacteria or other pathogens. One possible industrial tactic would be to paint a “resist” on surfaces to be protected from exposure, and thus selectively “etch” a metal, ceramic, or glass surface with radiation, UV, or micrometeorite exposure. Experiment will be needed to see if the results, as experiment parameters are modulated, offer economic value. One promising area for experimentation would be industrially crafted decoration of surfaces of consumer products for domestic consumption and export.

Attitude is everything. If pioneers adopt a mind set that sees this naked exposure to the cosmic elements as all liability, then that it will surely be. If they have the faith to see it as a blessing in disguise, they will be ready to turn this “liability” into a major asset for themselves. **MMM**



Lack of global biosphere on the Moon has a silver lining

By Peter Kokh

Relevant Readings from Back Issues of MMM

MMM # 8 SEP '87 "Colonists I.Q. Quiz": Q. 6 [MMM C #1]

MMM # 15 MAY '88, "Rural Luna" [MMM Classics #2]

MMM # 56 JUN '92, p 5 "Quarantine" [MMM Classics #6]

MMM # 79 OCT '94, pp 13-15 "Lunar Roads"; "Waysides, Service Centers, and Inns" [MMM Classics #8]

MMM # 83 MAR '95, p 5 "Tarns" - MMM # 84 APR '85, p 5 "Ghost Towns & Ruins" - [MMM Classics #9]

On Earth “the” biosphere is continuous, integral, and all-embracing. On the Moon, each settlement and outpost must maintain its own discrete minibiosphere, and do so very carefully. Lunans will live essentially and immediately, “downwind and downstream from themselves.” No global air circulation to diffuse pollutants, no shared ocean or boundary-defying groundwater aquifers to pollute. On the Moon, the great barren sterile out-vac will maintain a virtual mutual quarantine between all the several settlements and outposts.

Locally this discontinuity can be ‘postponed’. It will make no sense to have separate town center and suburban biospheres. Everyone living within feasible connection distance will seek to be interconnected. And there is virtue in this. The bigger the biosphere, the more stable and forgiving and satisfyingly rich and diverse it is likely to be, both in decorative greenery and in food and fiber producing plants. That does not mean there may not be separate political autonomies with their own little school

district and zoning peculiarity fiefdoms etc. But the important thing, the biosphere, will be a shared metropolitan responsibility. There may be some few separate neighboring installations, but these will be industrial facilities where prudent separation is maintained in case of a potentially polluting accident.

The biological quarantine that will reinforce the separateness of discrete outpost and settlement biospheres will offer an important plus. We've never built / developed / grown mini / artificial biospheres before, and the risk of biological collapse through imbalance, disease, or mismanagement will be higher than we would like – certainly for several generations to come. The provident availability of quarantine through the aegis of surface vacuum and the absence of groundwater will provide distributed, rather than shared vulnerability.

If there is disease or wholesale biological collapse in any one given minibiosphere, the chances of containing it there locally are greatly enhanced by this quarantine. Infection can be carried in by travelers and visitors, of course, but the odds of prevention are clearly enhanced by this separation.

Another benefit of this natural quarantine is that the town fathers and citizenry in each case can choose their own flora and fauna combinations, their own climate and regimen of seasons. "See one lunar town, and you've seen them all?" No way! Each can have its own natural ambiance, enhanced by differences in city plan, prevalent architectural styles, etc.

This quarantine-enabled variety will not only make the Moon a more interesting place for terrestrials to visit, it will draw the visiting Earthlubbers to visit more settlements, not just the main one(s), distributing income from tourism more fairly. Towns will choose their floral and faunal mix as well as architectural styles and other elements of distinctive and alluring ambiance accordingly.

For Lunans themselves, the result will mean realistic possibilities to "get away" and experience wholesome "changes of scenery" on vacation holidays as well as in business travels. Those needing to relocate and start their lives "over," will have the chance to do so. As on Earth, Lunans will be able to relocate for "life style" reasons.

The desolation of the out-vac is not only "magnificent," it is truly "beneficent." More next month!

MMM

MMM #95 – May 1996

The primitive roots of "Lunan" Culture, II

Last month we talked about the brute physical realities that will begin shaping Lunan culture from the day of our return and the establishment of the first overnighting beachhead outpost — fractional gravity, naked exposure to the cosmic elements, and the natural quarantine between outposts.

We continue the story with those brute physical facts that will insert themselves, if not on day one, then shortly there after to begin carving nascent Lunan culture even more deeply. The Moon is a very dry world. And its mineral assets lack several of the industrially strategic elements Earth's more generous endowment has lulled us into taking for granted. MMM



THE GLOBAL LUNAR DESERT By Peter Kokh

Relevant Readings from Back Issues of MMM

[Republished in MMM Classics #3] – MMM # 23 MAR '89, pp 4-5 "Gas Scavenging"

[Republished in MMM Classics #5] – MMM # 44 APR '91, pp 5-6 "Ice Caves"

[Republished in MMM Classics #6] – MMM # 51 DEC '91, p 5 "Ice Found on Mercury!"

[Republished in MMM Classics #7] – MMM # 67 JUL '93, pp 3–8 “Water & Hydrogen: lunar industrial grease”; “Hydro Luna”; “Reservoirs,” “Settlement Water Company,” “Xeroprocessing”

[Republished in MMM Classics #8] – MMM # 78 SEP '94, p. 3 “Why hotter Mercury may have polar ice while the colder Moon may have little.”

Compared to the Moon, **Tatooine**, of Star Wars I fame, would be a paradise oasis world. Away from the lunar poles, you can encircle the Moon, a 6,800 mile trek, without finding water. The closest thing to even the false comfort of a mirage will be Earth's blue oceans hanging tauntingly overhead in the black Nearside skies, some 238,000 miles away.

At the poles the story may be different. Volatiles such as water and carbon oxide molecules released on impact from rare cometary bombardment during local nightspan may have found their way to the safety of polar permashade coldtraps before local dawn, there to freeze out on the floors of craters whose interiors never see the rays of the Sun. The jury is still out on this, though indirect readings from **Clementine** over the lunar south polar region have been very teasing. Most sober estimates have been that the various loss mechanisms likely to be in effect (erosion from the solar wind, cosmic ray bombardment, micrometeorite rain) are likely to swamp the assumed rate of accumulation. That is, any ice deposits would be ephemeral and erode away or sublimate over time.

There is no one making such an estimate who would not be delighted to be proven wrong. Hopefully, we will not have long to wait. **Lunar Prospector**, next in line in NASA's Discovery Mission series, is due for launch next summer, equipped with precisely the right instruments to give us a definitive answer to the question. Any ice deposits **Lunar Prospector** might miss are probably too skimpy or thin to be of near term economic value.

The positive finding of substantial ice fields at the poles of Mercury, a world much closer to the Sun, has encouraged many. But Mercury's accumulation mechanisms may be significantly stronger. We simply have to wait and keep our fingers crossed, determined, should the results from **Lunar Prospector** prove negative, to make the best of “Plan B.”

“Plan B” is to scavenge the hydrogen nuclei or protons adsorbed to the fine particles of the upper meter or so of the regolith, thanks to the incessant buffeting of the lunar surface by the Solar Wind over the past 4 billion years plus. Hydrogen is present in this surface layer on the order of 1 ton of hydrogen per 10,000 of rock powder (regolith) along with lesser amounts of other volatiles: carbon, nitrogen, helium, neon and other noble gasses. 10,000 tons of regolith is the equivalent of the material removed from an excavation 3 meters deep by 30 meters wide and 40 meters long. Equipping all our ‘lith-moving equipment to heat the material handled in order to extract these gases for later separation would be a prudent and provident strategy. We have called this process “primage.”

Just how much water does this hydrogen source represent? One ton of hydrogen with 8 tons of oxygen (super abundant) yields 9 tons of water. If we could extract all the Moon's hydrogen to produce water, we could in theory cover all the lunar maria to a depth of say a centimeter or 3/8ths of an inch (and guess how fast that would soak in!!) Or we could make a crater lake 60 miles across and 30 ft. deep. Gathered all together it seems like a lot, but for the whole Moon? It's really very very little. No desert on Earth is as parched as the Moon. The Gobi, the Sahara, the Kalahari, the Takla Maklan – they are all dripping wet in comparison.

Even if **Lunar Prospector** confirms substantial water ice reserves at either or both poles, tapping them will not be easy. The ice temperature is likely to be extremely cold, the ice very hard and resistant to harvesting machinery which will be prone to break down all too frequently.

And should engineers come up with a simple smooth running system to extract this frozen wealth, how fast can we harvest it and put the water to work? In comparison to the rate at which these conjectured ice fields were laid down, any rate of extraction will completely swamp the rate of replacement. In other words, for all practical purposes, like oil on Earth, lunar polar ice is not a renewable resource. It behoves us to use it wisely. The number one demand will be for cryogenic rocket fuel. Make that number one in obscenity as well. We'd do best to use other lunar-sourceable fuels and save the water for recyclable uses in industry, agriculture, and biosphere support.

Will reason prevail? The temptations of impatience are always the strongest. A sustainable human culture on the Moon will have to be built on alternatives. Water-ice at the poles or no, Lunan culture will be characterized with an attention to water conservation beyond anything we have experienced on Earth, even in drought-stricken regions. Water is the blood of the biosphere. It is not free.

To what extremes will water conservation be carried? We have already spoken of the need to re-think airlocks to conserve nitrogen. The same will be true of water vapor. Conduits or pipelines and tankers carrying water or hydrogen in other forms (methane or ammonia, for example) will have to be designed for instant leak detection and ready repair. Materials of any kind with a hydrogen content (carbon or nitrogen too, for that matter) will need to be religiously recycled and reserved for intensive usage purposes.

Will Lunans carry things as far as the Fremen in the great Frank Herbert science fiction epic “Dune”? The desert-living Fremen wore “stillsuits that recycled their perspiration and urine into drinking water. Lunans may try.

We are used to life on a water-rich world with oceans, lakes, rivers, underground aquifers, and dependable rainfall. On the Moon there is none of this. Think for the moment of the ratio of plant matter to human matter. There is much more total mass of the former. Then think of the ratio of water to plant biomass. Again there is much more of the former. Will we be able to reproduce such healthy ratios within mini lunar biospheres? Both ratios on the Moon are likely to be much smaller, not too much above safety margins and dependent on high efficiency short-cycle turnarounds. That could be a prescription for disaster as it leaves little room for error or accident or other unplanned misadventure.

Reserves will have to be built up through frugality in usage. At the same time, every opportunity to add to those reserves from external sources must be taken within the limits of affordability.

We talk of a lunar settlement becoming self-sufficient. Ability to self-manufacture a large portion of its needs for domestic consumption is one thing. Ability to survive an interruption of lifeline supplies from Earth is something else. The umbilical cord can only be replaced with a yolk sac, that is with ample reserves of all vital supplies. Foremost among those are water, nitrogen, and carbon – scarce on the Moon, polar reserves or no.

Unlike us Earthlings, Lunans will hardly take air and water for granted. Culture and the language itself will be trans-figured by a high degree of attention to the conservation and renewal of these resources. Those who in the early days may have mined lunar polar ice for rocket fuel will go down in Lunan history books as trashing plunderers, no matter what their other accomplishments. Transportation is not everything nor the only thing and there are alternatives. Other lunar-sourceable fuel combinations and the rocket engines to burn them need front burner development, not continued consignment to paper studies on library shelves.

Because of this high danger of misuse, and of further postponement of development of alternatives, positive findings by **Lunar Prospector** should be greeted with concern by the thoughtful. But amidst all the excitement, who will want to listen to words of caution? There may never be a Lunan culture if we do not.



“Mother Earth?” – of course! – But “Mother Moon”?



Earth’s Atmosphere › The Moon’s Regolith layer



2 distinct, yet analogous types of “Cradle Blanket”

By Peter Kokh

On Earth we live on the interface of a land-sea surface and a generous atmosphere. At the bottom of this gaseous ocean, temperatures are greatly moderated, and most of the life-frying radiation that permeates outer space is filtered out – in particular solar ultraviolet and the high energy particles of solar flare storms. The atmosphere serves as a protective “cradle blanket” for life on Earth.

Much has been made of the absence of such cradle blankets on other worlds in the solar system. Venus’ atmosphere is crushingly thick, with a surface pressure some 90 times that to which we are accustomed. What’s more, it is extremely hot, sulfurous, and unbreathable.

Mars’ thin atmosphere is enough to support wispy clouds and occasional dust storms, but does a poor job of insulating the surface and filtering out harmful ultraviolet. On the plus side, it is thick enough to allow fuel-saving aerobrake landing maneuvers, even thick enough to allow for aviation to

become a major avenue of transportation in the opening of the planet's extensive frontier, equivalent to the land area of all Earth's continents. Yet for thermal insulation purposes and UV protection, Mars is functionally as airless as the Moon.

On the Moon and Mars, we will have to live in tightly pressurized habitats, and protect them with thermal insulation and radiation absorbing mass – either in the form of a piled up overburden of loose surface material or by placing our habitat structures in handy subsurface voids like lavatubes.

Fortunately, on both worlds, meteorite bombardment through the ages has built up a convenient surface layer a few meters thick of pre-pulverized material that is readily available for this purpose. This layer is called the “regolith” [Greek for blanket of rock]. Largely rock powder, it contains larger rock fragments and a considerable amount of tiny glassy globs that have resulted from the heat of meteorite bombardments.

While lunar regolith occupies the same physical site as topsoil on Earth, there is an enormous difference. Earth's topsoil is principally derived from wind and water erosion, which leaves the particles rounded, not rough and angular like the “unweathered” grains in moon dust. Terrestrial topsoils have varying but significant components of hydrates (water-bonded minerals) and of carbon-rich organics (decomposed plant and animal matter). They are also rich in nitrates.

Nor on the other extreme, can regolith be compared to relatively inert beach or desert sands. Sands are mostly silica, silicon dioxide. Lunar regolith is metal-rich in comparison.

In essence, we have to burrow under this rock powder surface blanket. We will live and operate largely not “on” the visible surface at all, but once again on an “interface,” this time between the fractured bedrock substrate and the powdery moondust top layer. Just as on Earth, we will survive and learn to thrive “tucked under a blanket” that provides thermal insulation and UV/Cosmic Ray/Solar Flare protection.

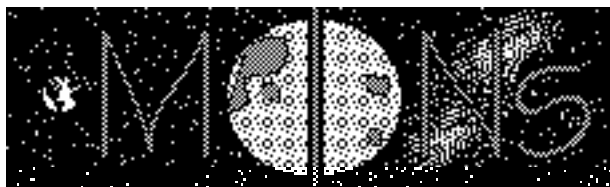
The regolith promises more than that. Its pulverized state makes it a handy and ample pre-mined endowment of the Moon's mineral resources. Lunar industrial development will build on this ready resource. More, having lain on the surface for eons, the regolith has soaked up incoming solar wind particles like a sponge. So it offers us gaseous wealth as well.

For thermal and radiation shielding, regolith can be blown, dumped, or bulldozed over our habitat structures. We can put it in bags to use for the same purpose but with greater convenience. Vibration compacted and then sintered by concentrated solar heat, it becomes a low performance solid (“lunacrete”) that can be used for paving or as blocks for constructed unpressurized outbuildings, or for decorative interior walls. Flocking regolith on molten glass as it is shaped, or on ceramic greenware before firing may make for an interesting artistic effect. Sifted free of the more finely powdered grains, it may make a suitable soil or rooting medium for both geponics and hydroponics food production.

Finally, regolith will “give up” some of its valuable elements very easily. Pass over it with a magnet to extract all the pure unoxidized iron particles (“fines”). Apply heat and extract all the adsorbed Solar Wind gasses: hydrogen, helium, carbon, nitrogen, neon, argon, xenon, krypton. Other elements (oxygen, silicon, aluminum, magnesium, calcium, and titanium and other alloying ingredients) can be extracted with more difficulty through a number of known processes.

Regolith seems a strange name. Pioneers may shorten it to **‘lith** (‘lith shielding, ‘lithscaping, ‘lith-moving equipment, etc.) By whatever name, it will play the major role in shaping lunar civilization and culture. For moondust is another very different yet analogous kind of cradle blanket. It will effectively tuck us in, motheringly, on the Moon. MOM

A tale of 2 Moons



Earth-facing & Earth-oblivious

By Peter Kokh

Relevant Readings from Back Issues of MMM

[MMM Classics #1] – MMM # 9 OCT '87, "Farside: Part I" – MMM # 10 NOV '87, "Farside: Part II"

[MMM Classics #7] – MMM # 69 OCT '93, p 7 "Seven Wonders of the Moon"

[MMM Classics #9] – MMM # 86 JUN '95, p 8 "Relayside"

The fact that the Moon keeps the same hemisphere forever turned toward Earth, while the other hemisphere is forever averted from Earth, may well have profound effects on Lunan culture, markedly distinguishing Nearside and Farside folk from each other. Much that applies to Nearside applies to Farside equally (mineral character of the surface, airlessness and exposure to cosmic weather, low gravity, thermal extremes, general dehydration, etc.) It is life against these constraints that will shape the Lunan character in general. But the presence or absence of Earth over the horizon will introduce profound differences in the cultural spirit of Nearsiders and Farsiders.

Nearside: Earth hangs in the black star-filled sky like some bedazzling jewel filling thirteen times the sky area with some sixty times the candlepower the Moon in our own skies, phase for phase. Its ever re-marbling blues, greens, tans, and whites will make it the prime repository of color in lunar "nature." Paradoxically, where the Earth is at a very high angle over the horizon in central Nearside (the "Crook-necks)", it will be less obtrusive into daily consciousness than closer to the Nearside limbs where it hangs comfortably above the horizon (the "Postcardlands"). Many Nearside homes, offices, schools, hotels etc. will have windows built to frame the ever changing and ever fascinating spectacle of Earth.

It is, of course, possible to look at Earth, even study it from the Moon, just for its beauty and everchanging detail – without being reminded of the human culture on its surface, and its overwhelming dominance of the Earth/Moon economic equation. Some pioneers will be more successful than others in resisting the intimidation of the spectacle. Others, feeling Earth's presence as overbearing, will work the harder to develop genuinely Lunan forms of culture and expression.

Again, paradoxically, the presence of the Earth may insert itself most strongly right along the limbs of Nearside where libration effects sometimes let it slip just below the horizon (the "Peekaboos"). Here in a broad 14 degree swath around the Moon from pole to pole where Earth oscillates above and below the horizon on a four week cycle, there may arise major settlements involved in the construction and maintenance of lunar solar power arrays beaming electrical power Earthwards – as well as a scattering of resorts. For the Peekaboos in general may become a favorite Lunan honeymoon destination. Here one can experience alternately, Earth kissing the horizon, and the rapture of Earthless skies.

Farside: Beyond the limbs (the "Peekaboos)", Earth is out of sight and out of mind. Lunar Farside is rather turned towards the "rest of the universe, a universe without Earth." Its skies instead are dominated by the unchallenged splendor of the Milky Way in a glory not yet fully experienced by any human (excepting brief out-the-porthole glimpses by busy Apollo astronauts circumnavigating the globe).

Not only will Earth be visually out of sight, without cable relay to Nearside, or without satellite relays, the home planet will be out of sight electronically as well. The resulting "silence" will be an invaluable asset to radio astronomers attempting to listen to the whispers of the universe in order to learn more about its structure, and whether or not it harbors other contemporary and equally curious techno-sapient species.


Terrain-wise, Farside has great impact basins just as Nearside does. But because the Farside crust is much thicker, the molten magma from the interior has had less success in reaching the surface and pooling in great sheets within these basins – to make "maria." Farside "seas" are smaller and scattered in comparison. There is no convenient "chain of seas" as on Nearside, making long excursions much more difficult. Farside terrain will be more of a challenge to builders of global highway networks.

Pioneers will come to Farside not only in the support of scientific installations like radio astronomy arrays, but for mineral resources that may conceivably occur there in richer concentrations than on Nearside. For whatever reason, over time, Earth being out of sight, out of mind, Farsider culture will evolve as more fiercely self-reliant, more willing to cut umbilical ties to Earth, more fascinated with the greater uni-verse out there, more enraptured by the siren call of the stars.

If we do someday succeed in establishing self-reliant but interdependent pockets of humanity beyond Earth orbit, to the point where some sort of "consolar" organization or association seems called for, a site on the lunar Farside might command top consideration for a headquarters or solar capital. Lunar Farside is conveniently close to Earth in travel and communications terms – and – the vast bulk of humanity will remain on Earth for the foreseeable future. Yet lunar Farside will be a place preoccupied

with “the rest of the universe,” a place unintimidated by Earth and its massive civilization and economy. In contrast, Earth will be very much present in the skies of Martian settlements, shining almost Venus-bright.

Any particular favorite sites? It would seem the best site for an extensive radio astronomy installation would be in Thomson crater in the north east of Mare Ingenii, the Sea of Ingenuity. A solar “capital” could piggyback on such an installation. But seen from approaching spaceships, easily the most visually striking feature of lunar Farside is the very dark mare-filled floor of the great crater Tsiolkovsky, dominated by the very bright central massif, the peaks of Konstantin. Such a site would have much romantic appeal and the symbolism of the name could not be more serendipitously propitious.

It will take time, of course, for cultural differences between longtime Nearsiders and longtime Farsiders to appear. Once they do, the differences might become the stuff of friendly rivalry. Yet the much broader shared conditions of life on the Moon will dominate both cultures in the end. 

MMM #96 – June 1996

Spacesuit Aversion

The quest for alternatives to a user-unfriendly interface

By Peter Kokh

Relevant Readings from Back Issues of MMM

MMM # 5 MAY '87, “M is for Middoors” – MMM # 49 SEP '91, p 4 “Visiting Amphibious Vehicle”

MMM # 53 MAR '92, pp 4–6 “Xity Plans” – MMM # 89 OCT '95, p 6 “Dock-Locks; Buppets”

Bryce Walden, Oregon Moonbase (bwalden@aol.com) writes:

“Sorry I don't have a firm attribution for this. It's a short note I took down while channel-hopping a couple of years ago. The speaker was an astronaut with some experience in a spacesuit, and he listed the “Five Worse Things About A Spacesuit:”

(1) You can't blow your nose. (2) You can't comb your hair. (3) You can't read your watch.

(4) You can't eat regular food. (5) You can't scratch an itch. (6) You can't light up a cigarette

(added by Ed.)

I suspect that the first and last complaints will be the most irksome, but also that these are just the handy lightning rods for an overall discomfort with what must be even to the most adept and practiced, an unnatural way to interface with an admittedly hostile environment. For that is just what a space-suit is, an interface with vacuum, with temperature extremes, and with the slow micrometeorite rain. Against other dangers of the alien environment, like cosmic rays and solar flares, it offers almost no protection at all.

The real point is that existing suits (at least) are not easy to don or doff, are cumbersome to get around in, interfere with free natural motion, and make manipulation difficult and clumsy. Where different pressures and atmospheric mixes are used in the spacesuit than in the habitat or vehicle supporting the sortie, pre-breathing is necessary, adding patiently or impatiently wasted hours before and after the venture in which little useful or satisfying can be accomplished. Spacesuits add to, rather than diminish the degree of difficulty and exertion the called for activity would of itself entail.

Improvements are certainly possible. The constant volume hard suit would eliminate any pre-breathing requirement and, if, as we have suggested, entry to and egress from the suit were made from a turtle-shell life-support pack backed into a conformal docking port, the whole airlock ritual with its wasteful exhausting of precious habitat atmosphere in each cycling, could be engineered out of existence. [cf. MMM # 90, NOV '95, “Dust Control”]. NASA may not feel the need, but frontier pioneers will soon demand such a development.

But why use spacesuits at all?

(1) Vehicles can dock directly with other vehicles and with habitats or other pressurized facilities, allowing “shirt-sleeve” access from anywhere to anywhere else.

(2) At any given settlement or development site, all pressurized facilities will run more efficiently if they are inter-connected via pressurized passageways and streets – save where activity with some risk of cross contamination requires prudent isolation. And such interconnection will create a larger shared mini-biosphere with greater forgiveness and buffering.

If the outpost or settlement is wisely designed, much routine outside activity such as system maintenance, vehicle maintenance, replacing volatile tanks, etc. can be done under the protection of a radiation shielding canopy or ramada. This would allow lighter-weight suits, more comfortable to wear, easier to get around in, and easier to manipulate through – a more user friendly vacuum-work interface.

And for field work? The turtle back suits will disencumber crew vehicles of the more massive air-lock apparatus. But personal one-man wheeled or walking vehicles with feed-back or virtual-reality-operated manipulators (“buppets” for body puppet, after muppet for mitten puppet), will again allow shirtsleeve comfort and freedom of motion as well as less restrictive personal activity for the occupant/driver/wearer.

The motivation and incentive to develop such replacement hardware will be strongly felt among those engaged in longer tours of duty, and considering “reupping” for duty tour extensions. As the “outpost interface” begins to morph into a “settlement incubator,” the demand for such hardware will squelch all bean-counting objections.

Predictably, there will be those few who need to feed their macho “rugged outvacsmen” image. Singly, or in small groups, they will put on suits and go outside to do their thing, ride around on lunar Harley hogs, go mountain climbing or whatever. Maybe they will have annual rebel outvac picnics at which they can pretend they are feeding their helmeted faces with roasted ribs and buttered corn on the cob after doing the three-legged race and the raw egg toss. Perhaps they’ll promote an amendment to guarantee their right to bear spacesuits.

Seriously, there will be genuine and worthwhile activities providing both adventure and challenge and which do require a spacesuit — like exploring a lavatube complex. Lunar spelunkers are sure to become a proud and exclusive fraternity, luring many a young kid with wanderlust and dreams of becoming a famous discoverer.

And there will be daredevils too, who in spacesuits, may try to walk a tightrope across a rille without a net, or free wheel down a mountain slope (look ma, no brakes) in an effort to see if there is after all some lunar equivalent of a terminal velocity in vacuum, and if so just how high it might be.

For most Lunans, visitors or settlers, wearing a spacesuit will simply not be an acceptable *modus vivendi*. Any sense of novelty, for kids or newcomers, will quickly wear thin. Face it, the spacesuit, as much as we take it for granted, is a quaint uncomfortable activity restricting contraption doomed to become a Flintstone-like anachronism.

The space suit will always be part of lunar frontier lore. But the stubborn situations which demand its use will be fewer and fewer as time goes by. As a result, it will quickly fade from everyday lunar life. Perhaps every able bodied lunan will still put one on now and then. But the occasion will be the semiannual depressurization drill, much like our school days fire drills, or lifeboat drills the first day out on some ocean-going or spacefaring cruise ship. MMM

MMM #97 – July 1996

For generations, Luna will remain a

Frontier

FRONTIER By Peter Kokh

Relevant Readings from Back Issues of MMM

MMM # 3 MAR '87, "Moon Mall"

MMM # 13 MAR '88, "Apparel"

MMM # 15 MAY '88, "Rural Luna"

MMM # 18 SEP '88, pp 3-4

"A strategy for following up lunar soil processing with industrial M.U.S./c.l.e."

MMM # 29 OCT '89, p 4 "Cottage Industries"

MMM # 32 FEB '90, pp 3-4 "Import-Export Equation"

MMM # 47 JUL '91, p 5 "Native Born"

MMM # 55 MAY '92, pp 7-8, "Moon Roofs"; "Shantytown"

MMM # 56 JUN '92 pp 3-4 "Harbor & Town"

MMM # 57 JUL '92 pp 4-5 "Space Xity Biomass Ratios"

MMM # 65 MAY '93, p 8 "MUS/cle Substitutions"

MMM # 83 MAR '95, p 5 "Tarns"

MMM # 84 APR '95, p 5 "Ghost Towns and Ruins"

"Praise the darkness, and creation unfinished!"

- Ursula K. LeGuin in "The Left Hand of Darkness"

In the Moon, we have a lifeless, barren world that would seem to be anything but friendly. We cannot deal with it at all as "naked apes," but only through the mated interfaces of technology and biospherics. Far more than other "alien shores" we've come across before, on this globe of unrelieved horizons of rock and rock powder against an unfiltered sky of cosmic hazards, we have little of past precedent to go on - little except the spirit of our pioneering past.

The Moon presents itself as a frontier in a much more pervasive and deep-challenging sense than has any previously unexplored and uninhabited niche on Earth. True, terrestrial frontiers have confronted us with challenges we don't have to worry about on the Moon: wild animals; strange diseases; the elements of fire, wind, water, and ice; and unfriendly natives.

Our acculturation to the Moon will have to be more far-reaching and all-encompassing than any humans have had to make to date. This will be necessary if we are someday to sit back and realize that through seemingly endless struggles with one problem after another, through battles lost and won, with ourselves as much as with our adopted world, we've somehow come, amazingly, to feel enough "at home" to experience real contentment, to let go of standby plans to return to Earth if in the end the rows of hurdles are just too much.

Frontier Interfacing 1.01

It would seem to some that the technical challenges to extended human presence on the Moon are either solved, on the way to being solved, or present only modest difficulties. In fact, most of the more flippantly offered solutions exist only on paper, or have been tried only in a laboratory without review by the engineers who would have to scale them up, and certainly not in any integrated systems approach. The early challenges include low-leakage pressurization integrity, thermal management, dust control, and overnighting power supply.

Beyond that, we must quickly progress beyond imported habitat volumes (rigid, inflatable, and hybrids) to (a) demonstration of building materials easily, efficiently, and reliably processed from lunar materials, (b) demonstration of fabrication of modules and modular elements made from them, and (c) demonstration of construction techniques based on them. Nor will this ever be a "been there, done that" step. Lunar pioneers, deprived of the enormous repertoire of manufacturing stuffs and building materials nowadays available on Earth, will be challenged into the indefinite future to come up with new solutions, better fit for newer applications. It will not be enough to demonstrate crude sintered iron technology or crude glass composites (Glax - suggested generic trade name for the whole family of likely formulations) technology. Lunans will have to aggressively seek to add to their stable of metal alloys, ever more specialized and higher performing glass and glass composites, ceramics, lunar concrete, sulfur composites, and other inorganic possibilities. All of these curiosities will not come on line together, or quickly. And until we've learned the whole suite of "lunar tricks," for all our achievements, we'll still be on a frontier.

"Nuke" solutions notwithstanding, there will always be more power available during dayspan (when "solar" can be tapped) than during nightspan, barring the achievement of some circumlunar su-

perconducting power grid in which dayspan solar cogeneration additions anywhere can feed nightspan power demands anywhere else without appreciable losses. This means that the dayspan–nightspan polarization of processing, manufacturing, and labor duties that we have forecast (energy–intensive and labor–light vs. energy–light and labor–intensive) is likely to characterize lunar living rhythms for a long time. Even after good solutions to the overnighting problem have been found, relics of this sunthly task–switching routine are likely to endure, having become endeared to the population.

Settlement architecture and general plans are likewise not soon likely to be mature. Regolith–buried modular towns are the early likely favorite, along with modular outposts within the protective cavernous “lee space” of handy lavatubes. But beyond that the vision lures of more “Earth–normal” type of habitat architectures within atmosphere containing mega–structures: domed craters and crater chains (“catennae”), vaulted rille valleys [the LRS “Prinzton Settlement Study,” detailed in the MMM series “Ventures of the Rille People” in MMM #s 26–33 JUN ‘89 – MAR ‘90], pressurized lavatubes, and similar farther–future dreams. It is dreams that provide any frontier with its fountain of youth, and with the vision of how it was, how it is on Earth taunting rugged lunar pioneers, they are not likely to ever be satisfied until they have been able to token–reproduce as much of Old Earth on the Moon as possible.

How extensive can lunar settlement become? Those of little imagination would go to their graves content and satisfied if we establish a vintage Little America type outpost with a handful of people. But the Moon is a very empty world, and only the size of the interdependent interplanetary economy can limit the growth of a lunar human population. Even if we limit our settlement areas, including biological natural parks and parkways, to the available “square miles of prime turf” (the definition will change as our capacities change: “ideal size” craters, crater chains, lavatubes, and rilles, etc.) – we will find enough of that to comfortable house and feed and recreate a population of some millions, only a fraction of whom need to be engaged in production for export. So from outpost to an appreciable off–world population, a progression that will take generations, the Moon will remain a “frontier.”

On Earth, pioneering a new territory has always been relatively easy. On the Moon we will have to cope with an across–the–board dearth of all the “in situ” assists and handicaps we have enjoyed in the past. We will find no trees, no wood, no bamboo, rattan or reeds or bark. There will be no food for the finding: no fish to catch, no game to hunt, no berries or nuts or seeds to gather. There will be no rich ores of iron, copper, or other metals to prospect. In addition to the lack of wood, there will be clay, no sod, no easy carve stone to use as building materials for shelter, not that we could seal them against the vacuum and cosmic elements if they were on hand. Nor, to make ourselves at home, will we find ready or almost ready to use art and craft materials.

We’ll be learning what to make and how to make it, over and over again, medium after medium, for a long time. In the process we will cope better and better with the exclusions and substitutions and compensations – the lunar facts of life.

We’ll have to adjust to material excesses as well as material insufficiencies. Regolith, regolith everywhere, with its intrusive and all–befouling dust – a challenge to housekeeping, to machinery with moving parts, to health. For most, that first fresh–off–the–lander impression of “magnificent desolation” will soon be replaced with an innocence–lost lasting impression of scenic monotony and boredom. Lucky the few for whom the variability of the lunar topography will never cease to amaze, with every new moonscape around the bend or over the rim! But for all, on the Moon we will be greeted only by rock, stone and dust: geology unrelieved by life with its verdant vegetation in so many forms, along with expanses of water: streams, lakes and seas. It is this combo of the awesome and the beautiful that has made our home world the lonely jewel it is, for as far off into the starry reaches as we have yet to thoroughly probe.

And then there are the black skies – as black by dayspan as by nightspan, unrelieved by alternating equal time periods of horizon to horizon sky–blue, variably pocked with restless white to gray clouds. Again, lucky the few who will never cease to be thrilled and soul–sucked by the clusters and clouds of stars – for these, when all is said and done, remain “the” frontier of human destiny.

Frontier Biospherics 1.01

If “gray engineering” has technical problems yet to be addressed, “green engineering” as it will be required on the off–planet frontier is in its earliest fetal stages. Most, amazingly not all, do appreciate that we cannot return to the Moon “to stay” without being prepared to aggressively phase in a mini–but functionally integral “biosphere” to reencradle ourselves on worlds without atmosphere, hydro–sphere, and native flora and fauna. We may have long taken it for granted, but that does not alter the

fact that we are quintessentially a symbiotic species. We must take our symbiotic partner with us as we move out into space. That partner is Earth–life in general, call it Gaia if you are not too hung up on the speculative excesses of the Margulis–Lovelock feedback theories. Sure we expect to be able to engineer an artificial symbiote: chemically regenerated air and water reserves, and foodstuffs à la Solyent Green. And need this approach we will, for cramped conditions on space stations and long–voyage spacecraft. After all, we have a long tradition of substitution of less than ideal life–support means aboard submarines, ships in general, and Arctic and Antarctic research stations. But long term, such measures can only support a caricature of human settlement.

Normalcy, such as a general population will find tolerable, will require “nature” in recognizable familiar terms to be involved. At first this involvement may be token, as with salad stuff cubicle farms, and CO2 scrubbing algal vats etc. But without the sure prospect and unquestionable commitment to a schedule of progress in the general direction of a self–maintaining diversified and balanced biosphere regenerating clean air and water, as well as producing ample food, fiber, and feedstocks of various utilities, frontier settlement will not be psychologically tolerable or self–maintaining in any sense.

Think of the ratio of water tonnage to biomass tonnage on Earth, and then of the ratio of biomass tonnage to the gross weight of the human population on Earth. Obviously, we have a tremendously long road to travel on the Moon or in other off–planet biosphere sites if these terrestrial ratios are the standards at which we ought to aim. Even with such high ratios, we are now seriously straining the recuperative capacities of our environment. How could we pretend to dream of not poisoning ourselves in very short order if, in off–planet mini–biosphere–wannabes the ratios of water:biomass: humans are only ridiculous tokens? Our mini–biospheres must be very extensive: not landscaped cities, but farming villages with farms. It is vegetation that must play host to man, not man to vegetation à la houseplants! Until this is the case, and it is a direction to move in, not something we can achieve at the outset, lunar settlements will still be “the frontier.”

Diversity of agricultural crops and complementary wild plant species, and a certain amount of post–human wild life as well (such as we find in our own urban and suburban and farming areas) will also be needed to provide a real biological flywheel as well as increasingly good mental health.

Frontier Economic Stratagems 1.01

Those whose bottom line dream is of a settlement invulnerable to the political and economic whims upon which continued lifeline support from Earth must always rest, face a long uphill struggle. In such a campaign nothing can be overlooked, certainly not the dollars, but neither the pennies. In addition to the obligatory money–earners like Lunox and a few other export items that have occurred to nearly everyone, there are innumerable less glamorous potential export commodities. (Anything Lunans can make for themselves at less expense than they can support an equivalent out of Earth’s deep gravity well, they can also sell to other space markets at a similar disadvantage: LEO and GEO lab–stations, factories, resorts; L4 and L5 space oases; and other off–planet pockets of human presence.) As anyone who has ever managed a budget knows, the nickels and dimes do add up, inexorably, often to sums that literally dwarf more attention–getting dollar expenditures.

Thus it is absolutely imperative that the domestic lunar economy not be neglected in favor of concentration on production of obvious exports. That would be self–defeating.

At the same time, it is clear from the limited suite of economically producible lunar elements as well as the limited manpower pool, that not everything we might want to have on the Moon can in any foreseeable future be produced there. These facts of lunar life suggest the M.U.S./c.l.e. stratagem in which Lunans concentrate on self–manufacturing the more Massive, Unitary, and Simple components of various items they need, and be content with importing ready to assemble works cartridges containing any complex, lightweight, and/or electronic elements required. An Institute of Lunar–Appropriate Industrial Design, perhaps on Earth, could design products from scratch for just such a collaboration. Lunar products, all exportable, could include habitat and ship and vehicle hulls and body components, tankage, furniture, appliance casings, etc. In aggregate, the total import burden could be decimated.

The “yoke sac” stratagem is another “piece of the puzzle.” Lunans must move to quickly extricate themselves from realistically fickle umbilical dependence on Earthside policy–reviewers. Instead of supplies received “just on time,” the current newly embraced conventional wisdom, settlement fathers need to over–import any strategic commodities without which outpost failure is certain, swift, and without recovery. If economically recoverable water–ice reserves are not confirmed at the lunar poles, hydrogen will certainly be at the top of that list, along with sister volatiles carbon and nitrogen. A tank

farm with a 2–5 year supply (based on growth assumptions) of methane and ammonia ought to do the trick.

Added reserves that need to be built up are copper and other industrially important metals, scarce or not yet economically producible on the Moon, including needed alloy ingredients; nutrient additions for regolith–soil–based farm production; pharmaceuticals or their feedstocks. We'll also need well-stocked tool cribs and parts stores. The settlers need reserves to buy time in which to open up alternative sources if the squeeze is put on, deliberately or as an unfortunate side-effect of some unrelated policy development on Earth. Strategic planners must seek to open alternative off-planet sources of critical materials in seeking to build an independent capacity to self-replenish them. This is the frontier.

Opening the Solar System in general is part and parcel of securing the future of the lunar settlement. Other off-planet pockets of humanity will make more dependable trading partners. Early daughter frontiers may include asteroid mining operations, a Mars colony and processing and manufacturing facilities on its moonlets, Phobos and Deimos.

But they will also include the genteel “suborbs” – more sophisticated and Earth-reminiscent space oases settlements – or so the expectation goes. In truth, these artificial outside-in worldlets will be “lunar frontiers” in disguise, where Made-on-Luna items and lunar raw materials will be less expensive than more desirable, more sophisticated equivalents made on Earth.

Attracting Immigrants will also be vital to maintain and grow the settlement in a viable and sustainable fashion. To do this, the powers that be must “sell” the frontier, making its obvious and undeniable hardships come across as “more than worth it,” however counter-intuitively, in light of the rewards. If the “sell” is done right, it will attract the right people, the ones who will be able to contribute to the building of the frontier, and who will find themselves amply rewarded by the intangible satisfactions that will come, however haltingly, from being able to make a real difference at ground floor level.

Immigration – selling the frontier: Frontier Adjustment 1.01

Many are the psychological adjustments that will be needed to be made, some of them over and over again, by those who have taken the plunge and made an honest commitment of the rest of their lives to their new adopted home world. They will have chosen to forsake the world of their birth with all its real attractions and advantages.

Consumer types who crave the latest and finest need not apply. Early settlement “issue” wares and wares will be crude and esthetically uninteresting, however serviceable. Local arts and crafts will develop slowly, and with them, the prospect of nicer things. The small market in tandem with other off-planet markets, will mean markedly fewer choices.

Those needing lots of elbow room will also have a hard time of it. Even with inflatable and hybrid rigid-inflatable prefab shelter imports, per person private and common spaces alike will be at a premium until shelter can be built routinely and generously with local materials we've learned to process and fabricate and erect on the Moon.

Occupational options will at first be limited, but expand in diversity exponentially as the population grows. There will be those with the psychological “right stuff” who will need at least temporary occupational reassignment.

A very real sacrifice, one most do not expect, is the enormous physiological obstacle that will build up over years in the way of ever returning to Earth, a place where one would suddenly, not gradually, weigh 6 times (not 1/6th) more than one had become accustomed to bearing. Earth, and its beauty and meccas of many kinds, will inexorably become a destination out of reach except for the physically most determined.

Risk acceptance will be a frontier trait that affects much more than the prospects of ever reneging on one's settler commitment. Lunans will live far, in gravity well terms, from Earth's encyclopedic problem-fixing resources. Some equipment may rest unused, waiting unaffordable repairs or parts. “Medical Triage,” however, will be a more powerful concern for the less than supremely dedicated. Despite possible development of time-delay-scourged labaroscopic surgical teleoperation procedures, many less common medical crises, manageable on Earth, may mean certain death on the frontier.

Frontier Prospects

It is characteristic of any frontier for there to be too many jobs needing done for the too few people available to do them. The frontier puts a strong premium on multitalented individuals. Everyone

has the opportunity to be useful, even the young, the handicapped, and the elderly. And these ground-floor openings will give all a chance to make meaningful, satisfying differences that will be worth all the hardships.

The LeGuin quote at the top sums it all up. The darkness of hardships and sacrifice are undeniable. But nowhere is Creation more Unfinished than on the frontier. And it is that opportunity for us to help finish creation which makes being human more than a cosmic joke. MMM

MMM #99 – October 1996



To/From the Lunar Surface

By Peter Kokh

How do we cut expenses for landing on the lunar surface? Use as low-mass a landing vehicle as possible to bring down the equipment, supplies, people, etc. Leave unneeded mass in orbit. See last article. In addition, we can pursue these strategies.

Fuels and Oxidizer from Moondust

- **Liquid Oxygen** for fuel oxidizer is the most obvious opportunity to save. There are many ways LOX can be processed from the lunar regolith soil. “LOX” can even be used to refuel Moonbound vessels in low Earth orbit.
- **Less potent but quite adequate, powdered metals** (alone or in a liquid hydrogen slurry) can be used in place of hydrogen. Abundant lunar aluminum, iron, calcium, and magnesium will do well. **Aluminum** oxygen combination is the most potent but it will take a lot of equipment and energy to produce the aluminum powder. (A 75% aluminum, 25% calcium alloy is easier to keep powdered). Pure **iron** powder is everywhere, especially on the mares, and can be produced easily by passing over the soil with a magnet. The exhaust is rust powder which will fall harmlessly back to the surface without degrading the lunar vacuum.

Densifying Hydrogen Extenders

Hydrogen may make the ideal fuel, but on the dry Moon, even if there is some polar water ice, hydrogen will be a precious commodity and using it – at least in unextended form – will constitute an obscene waste of an invaluable and limited and expensive resource. Two ways to use it as a fuel extender are as a slurry medium for powdered metal fuels (above) and in chemical combination with other elements. One of the hydrocarbon analogs of Moon-abundant silicon will do such as Silane, SiH₄, the silicon analog of methane, CH₄. According to Dr. Robert Zubrin, Silane can be produced in a Sabatier Reactor (the nuclear thermal powered device he successfully demonstrated for the production of methane fuel from Mars’ atmosphere).

Economic pressures (impatience for short term advantage and profit at the expense of long term sanity) to use precious lunar hydrogen reserves directly will abound and there are many “damn the future” space advocates ready to do just that – some of them prestigiously placed. By treaty or lunar charter, it is in the interest of future Lunans and their civilization to restrict such use with adequate safeguards and stiff penalties.

Landing without Retrorockets

Mars fans are quick to point out that thanks to its atmosphere, it will be cheaper to land people and cargo on Mars than on the Moon. But there are a few tricks other than aerobraking that can be used on the Moon in similar fashion.

- Krafft Ehrlicke described a “Lunar Slide Lander” that would dump horizontal momentum into a prepared regolith runway in Lunar Industrialization and Settlement – Birth of Polyglobal civilization” in “Lunar Bases and Space Activities of the 21st Century” ed. by W.W. Mendel, Lunar and Planetary Institute, Houston 1984, pp. 825–7.
- In what we hope is an improvement on this idea, Doug Armstrong and I published an article on “Enhanced Harenobraking” [sand-braking] in MMM # 55, cited below. It is conceivable that some lim-

ited application of this trick could be used to shed some of the momentum of an incoming personnel carrier.

- Cushioning Farings of non volatile material – e.g. metal and ceramic foams might land G-hardened payloads on the Moon intact, in specially restricted landing zones where they can then be “harvested.”
- Chicago inventor Ed Marwick has put forth an elaborate proposal in which guided payloads enter a sloping chute dug into surface and encounter ever denser sprays of regolith dust, slowing the capsule down to a halt. Such a facility would have to be as long as a mass driver per level of Gs to be tolerated.

Loading and Unloading Facilities

The earliest ships coming to the Moon to set up operations in any given development area will be “self-unloaders” weighted down with the cranes and winches needed to unload and reload themselves. Landing on and launching from the Moon will take less fuel and be cheaper, once such equipment is set up on a site, thereby establishing a “port.” “Go anywhere” craft will operate at a competitive disadvantage as compared to craft designed to trade via an established lunar surface port facility. Population will follow, so that port-establishment will tend to be outpost and settlement site preemptive. (The same applies to the establishment of fuel processing facilities and fuel depots, harenobraking smoothways, electromagnetic launchers and catchers, etc.)

Electromagnetic Launchers

Mass Drivers have been principally investigated for the regular continuous shipment of unprocessed lunar regolith into space for production of building materials for Solar Power Satellites and Space Settlements. Such devices provide very high G launch over relatively short mag-lev tracks.

Other elaborations are possible:

- value-added pelletizable processed materials
- G-hardened small size manufactured items
- Larger items (cargo holds, personnel pods) in more potent, longer, slower accelerating launch tracks

Reversing mass drivers or Mass Catchers which catch and brake landing payloads have been mentioned and need further investigation for high traffic situations. In most cases this will not require a new facility, just a new “reverse” mode use (where launch demand allows) for an existing mass driver.

Mass Drivers-Catchers are expensive big ticket items. They will lower costs to and from the lunar surface only when amortized over a long period of high traffic use.

Relevant Readings From MMM Back Issues

MMM # 6 JUN '87 “Bootstrap Rockets”

MMM # 55 MAY '92 “A Better Slide-Skid Lander? Enhanced Harenobraking”

MMM # 56 JUN '92 “Harbor & Town”



MMM #100 – November 1996



The Lure of the Moon’s Hidden Covered Valleys

In this Apollo 10 photo of Hyginus Rille in Sinus Medii (central nearside, 5°E, 8°N) are visible a number of “gaps” in the rille. The arrow points to the most prominent of these, about 10 miles long.

The only geologically viable explanation is that this “interruption” is an uncollapsed segment of an original lava tube once well over a hundred miles long. Someday such ready-made sanctuaries from the cosmic elements may house the bulk of the Lunan urban population. Much more on pages below in this special “Lava Tube” issue of MMM.

LAVATUBES Relevant Readings from MMMs Past

Articles on Lavatubes

- MMM # 25 MAY '89, p 4, “Lava Tubes”
- MMM # 44 APR '91, pp. 2-4, “Oregon Moonbase”
- MMM # 44 APR '91, pp. 5-6, “Ice Caves”
- MMM # 73 MAR '94, pp. 3-5, “Urbs Pavonis, the Peacock Metroplex: the Site for Mars' Main Settlement.”
- MMM # 93 MAR '96 p 16 “Visit Oregon Moonbase”

Some Articles On Other Relevant Topics

- MMM # 3 MAR '87 p. 10, “A Concrete Moonbase”
- MMM # 5 MAY '87 “LunARchitecture;” “Weather,” “M is for Middoors”
- MMM # 8 SEP '87 “Parkway”
- MMM # 12 p 8 “Welcome to Moonbase” by Ben Bova
- MMM # 15 MAY '88 p. 12 “Sunflower Solar Collector”
- MMM #s 26-29 & 31-33 “Ventures of the Rille People” LRS prize winning Prinztion Settlement Study (double- vaulted pressurized rille-spanning agricultural village megastructures)
- MMM # 37 JUL '90, p 3, “Ramadas”
- MMM # 50 NOV '91, pp. 6-8 “Hostels, Part IV: Hostel-Appropriate Architectures”
- MMM # 55 MAR '92, pp 4-6 “Xity Plans”
- MMM # 74 APR '94, p 5, “Shielding and Shelter”
- MMM # 89 OCT '95, pp 3-5 “SHELTER on the Moon: Digging in for longer, safer stays.”

LAVATUBES Twelve Questions About Lunar

> **What is a “lavatube”? How are they formed?** A lavatube is a relic of a river of molten lava, self-crusting over on the top as the exposed surface cools, and then at least partially voided out as the lava spreads out eventually on the surface as a sheet.



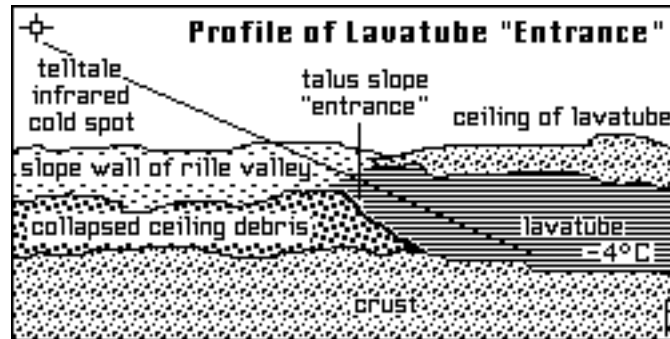
> **Where do we find them on Earth? in what kind of terrain?**

On Earth we find lavatubes in the flanks of shield volcanoes such as Mauna Loa/Kea in Hawaii and Medicine Lake in California. We also find them wherever we have had vast state-sized flood sheets of lava, as in Washington-Oregon, the Deccan flats of southern India, in northeast Siberia, and elsewhere.

> **How sure are we that similar features exist on the Moon?**

The lavatube-rich lava plains found on Earth are geologically analogous to the maria or Seas we find on the Moon. On those grounds alone, we would have a high expectation of finding lunar tubes.

But for a second higher order of evidence we also have, in the same type of terrain, long sinuous valleys on the Moon called rilles (the Latin class name is rima). We have found hundreds of these features in orbital photographs and have visited one (Apollo 15's visit to Hadley Rille). The consensus explanation of such features is that they represent collapsed lavatubes. For a third even more convincing order of evidence, some lavatubes are clearly segmented with interrupting stretches of valley-free surface [see the photo on page 1 of this issue.] These can only be sections of the original lavatube that have not collapsed and remain still intact. Such sections should by themselves be enough to give future lunar developers ecstatic dreams. But if there are partially intact tubes, it is inconceivable that elsewhere, if not nearby, are to be found wholly intact tubes. Lavatubes are a natural concomitant of maria formation on the Moon, and will be common.



> **Are they near surface objects only?**

Those we have direct or indirect evidence of (from rilles) are/ were near surface features. But keep in mind that the maria were filled with a series of lava floodings, and the formation of each successive sheet should have its own lavatubes. On the plus side, lavatubes in deeper layers have been more protected from collapse due to later meteorite bombardment. On the minus side, some, maybe most (a defensible guess for whatever your temperament), were filled up and plugged by later episodes of flooding. Deep tubes are unlikely to be discovered from orbit or from the surface. We could hope to find some of them serendipitously (where tubes in successive levels just happen to cross) by radar soundings taken on the floors of near surface tubes by actual explorers.

> **How might typical lunar lavatubes differ from typical tubes found on Earth?**

- (1) The formative episodes of lava sheet flooding on the Moon are all very ancient events on the order of 3.5–3.8 Billion years ago. Surviving lavatubes on Earth are all much much younger than that, some only thousands of years old.
- (2) In addition to being very ancient, lunar lavatubes differ in scale. Probably because of the lower gravity in which they formed (1/6th Earth's) tube-relic rille valleys already observed, photographed and visited run an order of magnitude (**ten times**) typical terrestrial dimensions in width, ceiling height, and total length. Lunar tubes are BIG.
- (3) Lunar lavatubes have never been exposed to air or water (unless a comet happen to pierce the ceiling and vaporize inside with some of the volatiles freezing out on the tube's still intact inner surfaces – a real “lucky strike”!). Like tubes and caves on Earth, the temperature will be steady, but colder (Earth in general is 50°F warmer than the Moon because of the oceanic-atmospheric heat sink.)

> **How intact and stable would lunar lavatubes be? How prone to future collapse, total or partial?**

Any lavatubes that have survived to this day wholly or partially intact are likely to continue to do so for the rest of time. The vast bulk of major asteroidal bombardment which has pocked the Moon took place in the first billion years of the Moon's history. Lunar lavatubes, not subject to any sort of active geological forces or to any kind of weathering are perhaps the safest, most stable, protected volumes to be found anywhere in the solar system. They are veritable vaults, sanctums, sanctuaries we can bank on – no bet-hedging needed.

> **What aspects of lunar lavatube internal environments are most attractive for human purposes and to what uses might we put them?**

- 1) “Lee” vacuum protected from the micrometeorite rain, from cosmic rays, from solar ultraviolet, and from solar flares, and unlimited volumes of it, is a priceless and odds favoring handicap toward lunar outpost and settle-ment establishment, expansion, and maintenance. In these conditions, only sim-

- ple unhardened lighter weight pressure suits need be worn, for much greater safety, comfort, and convenience. Lee vacuum is ideal as well for storage and warehousing and in-vacuum manufacturing.
- 2) Steady temperatures at all times (-4°F), protected both from dayspan heat ($+250^{\circ}\text{F}$) and nightspan cold (-200 some $^{\circ}\text{F}$), the “body-heat” of the subsurface Moon being much higher than the “skin” heat of the exposed surface
 - 3) Lunar lavatubes are dust free. The regolith Moondust blanket is the result of eons of micrometeorite bombardment or gardening of the lunar surface. The unexposed surfaces of lunar lavatubes have been protected from all that and, good housekeeping measures adopted and religiously followed, will remain dust-free sanctuaries. Given the insidious invasiveness and machinery- and lung-fouling character of moondust, this asset is a clincher!

For construction purposes, shielding now provided as a transcendental given and dust-control vastly easier, lavatube sites will be much simpler and easier places in which to build. We have only pressurization to provide and maintain within these natural macro-structures.

As a package, lavatube assets effectively remove (squelch, eradicate, nuke) most of the common objections to the Moon as a development and settlement site, reducing worries to lack of around-the-clock sunshine (an engineering energy-storage and usage/scheduling question) and gravity one-sixth Earth normal (as if life hasn't always been able to adapt to anything!).

> Are there any more special resources we might find in lunar lavatubes here and there as extras?

Mineralogically, lavatube surfaces and their host terrain will be boring, fairly homogeneous basalt. Other elements, not present in local basalt, can be mined and processed elsewhere and the products made from them brought to the site. But not to be overlooked is the possibility that we have hit the cosmic jackpot with a volatile-rich comet strike of just the right size to puncture, but not collapse, a lavatube. Frozen volatiles would be the prize. These would not be subject to most of the loss mechanisms that will surely operate in polar permashade ice fields (micrometeorite bombardment, solar flares and solar wind, cosmic rays, splashout from other impacts). To date, the only (and it's inconclusive) teasing evidence we have is an anomalous reading over western Mare Crisium that on first interpretation would seem to indicate subsurface water-ice. This reading has been (but should not be) routinely dismissed as spurious.

> What lavatube uses are near term, what uses are more challenging and likely to be realized only in the far future?

Warehousing and storage; industrial parks; settlement as opposed to outpost; archiving. All of these can benefit from the use of lavatubes much as we find them, without wholesale modification. The idea of pressurizing tubes for more “terra-form” settlement presents a number of enormous hurdles (sealing methods, sealant composition, pressurization stress, importation from Earth of astronomical volumes of nitrogen, etc.) and while in toto vastly easier than wholesale terraforming of a whole surface (e.g. Mars) is still something we will not tackle for some generations perhaps.

> How much total ready to go protected volume are we talking about?

For political purposes internal to the pro-space movement, let's express our back-of-envelope guesstimate range of the total available volume of intact lunar lavatubes in terms of O'Neill Island III Sunflower space settlement units. That's ready-to-occupy-and-use-NOW (for those without 1-G and 24-hour sunshine hangups – they can wait the generations it will take to build Sunflower units from scratch !)

The surface area of the host terrain, the lunar maria, comprise some 17% of lunar surface = 2.5 million square miles – compare with 3 million square miles for continental U.S. Now if (we have to start the argument somewhere!) we assume that available floor and wall terrace surface of intact lavatubes compares to 1/1000th the taking 1/1000th of this aggregate lunar maria surface area, we get 2,500 square miles. This is in our estimate, a very conservative fraction. Counting supposed lavatubes in lower level lava sheets, 1/100th is a fraction that could be closer to reality. That would yield 25,000 square miles, an area comparable to West Virginia.

Subtracting for window strips (as we have for lavatube upper walls and ceilings), an O'Neill cylinder, if ever realized in full ambitious scale, might have 100 square miles of habitable inner surface. Argue about the figures, it won't change the overall picture. We are talking about ready to occupy network of lunar lavatubes that compares to 25 to 250 Island III units. If you are going to hold your breath

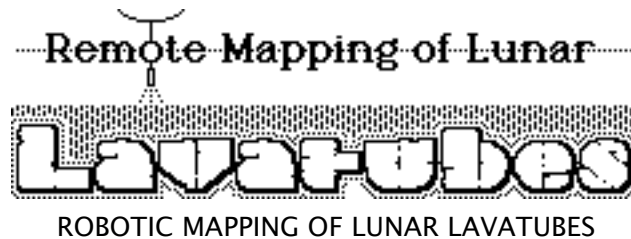
until these free space oases are built, I can only hope your life expectancy is much more Methuselah than mine {P. Kokh}.

> **Can we expect to find other similar hidden covered valleys elsewhere in solar system?**

Yes, as they seem to be a standard concomitant of lava sheet flooding and of shield volcano formation, we might expect to find lavatubes on Mars, Mercury (the temperature swing refuge would make them hot property), Venus (they would be too hot, and share Venus' over-pressurization), Io (protection from Jupiter's radiation belts), and even on little Vesta..

> **By what Latin class name are such features likely to be referred?** (e.g. rima = rille)

Cava, tubus, and **ductus** are available Latin words. The latter better indicates the mode of formation.



Tele-Spelunking on the Moon

[Reprint of MMM #44, April '91, page 6]

EARTH-BASED SEARCHES FOR LUNAR LAVATUBES

Writing in **Starseed**, the newsletter of Oregon L5 Society, Oregon Moonbase researcher Thomas L. Billings discusses ways to search out lunar lavatubes. Tube openings are hard to spot by camera unless you are right on top of them [but see note below]. While intelligent lunar base siting will require better orbital mapping than provided for the Apollo landings, the best method may be to look "through" the rock. The severe dryness of the lunar surface should make this possible for orbiting radar. (Airborne radar has been used successfully to find lava tubes on the big island of Hawaii.)

To provide deep radar imaging, the antenna diameter must be four times the radar wavelength being used. To penetrate deeply enough we'd need a wavelength of 5-20 meters, meaning an antenna 20-80 meters across! That's a lot of mass to put into orbit along with the ancillary equipment.

Billings suggests a way out. Readings from a number of smaller antennas in an interferometer array can substitute, synthesizing an image. It will be tricky to do this in orbit, and an intercontinental Interferometric is an option Using a 7 meter wavelength, you'd have a 250 meter resolution and a penetration of 70 meters, good enough to detect a convincing sample, given that many tubes are likely to be larger than this.

However, a considerable amount of power will be needed if the signal returning to Earth is to be detectable. Computer algorithms needed to sift signal from noise are getting better. Nor need the search extend beyond a few months, so maybe the expense wouldn't be out of line with the rewards.

TB

Editor's Questions. & Suggestions:

- a. Would it be practical to intercept that signal in lunar orbit where it would be stronger?
- b. Would Earth-based searches be limited to central nearside?
- c. We could use the same instrumentation package to search for tubes on Mars, Mercury, Venus, Io, and Vesta, worlds with shield volcanoes and lava sheets.]

Using Orbiting Infrared Cameras to Find Collaborating Evidence

According To Bryce Walden and Cheryl Lynn York of Oregon Moonbase, orbiting side-looking infrared detectors may on occasion peer into the entrance of a fortuitously oriented lavatube, detecting

its characteristic subsurface temperature, clearly distinct from ambient surface readings, in sunshine or out. Illustration in previous article. [MMM](#)



ROBOTIC
On Site Exploration & Surveying
LAVA TUBES

ROBOTIC ON SITE EXPLORATION AND SURVEYING OF LAVATUBES

By Peter Kokh

We are back on the Moon, to stay it seems, and we've detected a number of lavatubes from orbit, some handy to our first beachhead outpost. The catch is that there are so many things needing priority attention that we cannot afford the manpower and equipment costs to outfit even a single lavatube exploration expedition. But if we don't "go in" and actually explore and survey, how can we plan intelligently to "move inside" in concrete particulars?

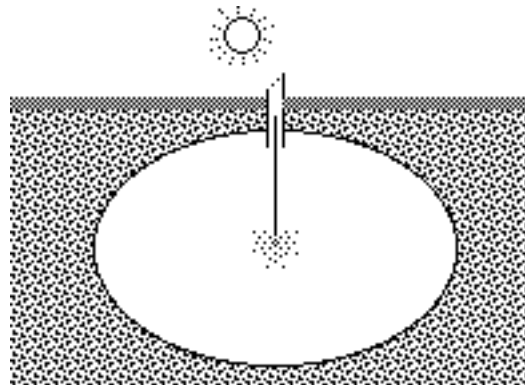
Here is a way we can survey in detail all the lavatubes we have detected remotely from photographic evidence, from orbiting radar and infrared equipment. The costs, in comparison to a single limited human expedition, would be negligible.

A surface crawling drilling rig, using high resolution orbital radar lavatube location data, finds its initial drill point over an indicated tube site. This rig can be teleoperated or manned. Given the repetitive nature of the tasks involved, a highly automated remote monitored operation will be ideal.

(1) Its first task is to drill and stabilize (with a sleeve? with side-wall fusing or sintering lasers?) a hole through the surface and penetrating the lavatube ceiling some tens of meters down. The hole might be only a few inches in diameter.

(2) Next the rig winches down through the shaft hole a radar-mapping instrument and/or CCD optical camera down to a height midway between lavatube ceiling and floor (determining that position is the first task of the radar device). Then a flare attached to the bottom of the instrument package is released and dropped. The radar mapper and camera pan 360°, and from near vertical up (zenith) to near vertical down (nadir). The instrument package is retrieved. A latitude/longitude/altitude benchmark is then lowered to the tube floor directly below.

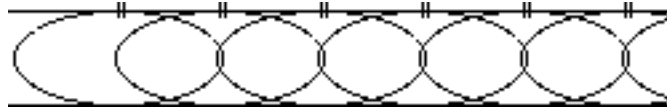
(3) The rig then winches down to the same point a length of fiber optic cable, securing the top end to the collar of the shaft hole. At the top end is a solar light concentrator which passively gathers available dayspan sunshine and channels it into the optic fiber cable. At the bottom end a light diffuser scatters this light in all directions.



The idea is not to provide future human explorers within the tube with enough light, throughout the surface dayspan period, to find their way around with the naked eye, but only with enough light that they can find their way using off-the-shelf night-vision goggles. Of course they will carry battery-pack

spotlights to light up areas needing closer inspection, as well as for emergencies e.g. they are forced to stay inside after local sunset on the surface above.

(4) Meanwhile, data from the radar/camera probe is being turned into a contour map of the lavatube's inner surfaces. From this map, it will be clear in which direction the lavatube runs and the location of the next drill hole can be determined, picked so that data from it (and the reach of the left behind "solar flashlight" overlap conveniently).



As the instrument package is removed from each successive shaft hole, another passive solar flash light chandelier is installed. On and on until the entire intact lavatube is surveyed from source to outflow. The rig then moves to one end of the next orbitally detected site to be investigated.

The result will be a set of tube surveys and maps from which preliminary rational use scenarios can be put together all prior to commitment of man-hours and man-rated equipment packages. Now, with all of these robotic surveys, safely made, when we do go in to explore or set up shop, we can be sure that the tube section picked is right for the purpose intended, including the offer of adequate expansion room for foreseen development options.

This is the basic idea. Possible embellishments are designing the solar flashlight chandeliers to serve as line-of-sight relays for radio communications by exploring crews, and/or as direct radio antennas to the surface.

If the tube surveyed by the surface-crawling robot drilling rig has already been picked for future development, a "sleeve-bag" of sundry provisions and resupplies could be lowered to the tube floor beside the benchmark prior to sealing the shaft with the solar light fixture apparatus. These provisions would lighten the burden in-tube explorers need carry along. Alternately, the solar light fixtures could be removable if the shaft is needed for lowering provisions or other narrow diameter equipment to the area below it.

This exploration plan will only work, of course, for those near surface tubes that have been sniffed out by our orbiting probes. But that will be an important start! MMMM

MMM #102 – February 1997

Technical Comments on the MMM #100–101 Lavatube Articles

By Bryce Walden, Oregon Moonbase

Congratulations to **Moon Miners' Manifesto** on its 101st issue! We have enjoyed every issue, chock full of interesting and provocative ideas on the development of the space frontier.

The Oregon Moonbase team especially appreciates the extensive coverage given to the topic of lavatube caves in Issue #100. Peter Kokh did a lot of work developing the arguments and provided some very nice illustrations of various concepts.

In the interest of completeness, I would like to add a few technical comments as they occur in my reading of the articles.

Lavatube Stability vs. Human Activity

In "Twelve Questions About Lunar Lavatubes" Kokh correctly states that caverns that have survived for over 3 billion years are probably very stable. Yet I feel obliged to add the caveat that human activities could at times threaten that safety. A lavatube that has survived may still have suffered trauma that makes certain parts of it weaker, such as a meteorite strike over part of the roof. Sections that survived the relatively minor moonquakes over the millenia may fail if we blast during construction. Also, lava that is strengthened by incorporating super-strong anhydrous glass may weaken over time if exposed to water vapor from atmosphere or other gas-releasing activities. Sealing and pressurizing a lavatube will also introduce new stresses, as he himself mentions in a subsequent article. To mitigate these effects, there are engineering precautions that can be taken on a case-by-case basis.

Lavatube Temperatures

The "steady temperature" of -4°F is based on Apollo temperature measurements that reached equilibrium within several centimeters from the surface and stayed fairly constant from there to as far down as the astronauts could measure, roughly 2–3 meters. Deep mines on Earth get quite hot from heat bleeding away from the mantle; this could happen on the Moon, too, but probably to a much reduced extent due to the relative coldness of the small lunar core. As a rule lavatubes don't have much vertical development but run parallel to the surface. There may be older lavatubes in deeper layers of lava, as his article points out. Once again, the real problem is likely to be human activity. Lavatubes are good insulators. On Earth, cold air can fall into a lavatube in winter and remain below freezing through summer heat. Our case will be just the opposite. Human activity generates a great deal of heat, and the lavatube is a relatively closed environment. For awhile this could be an advantage, and raise lavatube temperatures to comfortable levels, but we are likely sooner rather than later to have to engineer some heat-sink solutions. Changing temperature can also be a source of stress to the cave vault.

Gross Available Lunar Lavatube Volumes

In terms of ready volume available now, we did a poster session at the 22nd Lunar and Planetary Sciences Conference that partially addressed this question. Cassandra Coombs, for her doctoral dissertation under Dr. B. Ray Hawke, identified a number of probable lavatube sites from high-resolution Apollo photographs and Lunar Orbiter pictures. Only the largest possible candidates were resolved by these sources. Cheryl Lynn York and I selected the largest 20 of these sites. Making a working assumption of circular caves of width and length identified by Coombs, then half-filled with congealed lava or breakdown, we computed over 3 billion cubic meters of volume, nearly 14 million square meters of "floor" area, or about 0.0531 of Peter's "O'Neill Units" of 100 square miles. The average of these twenty large lavatubes was 470m diameter, length 1,370m, roof thickness 66m, floor area 687,685 m^2 , and volume 157,908,640 m^3 . Incidentally, these "Top 20" lavatube caves were located in only four rille formations, with rille "collapse trenches" separating the various caves.

Lavatube Volumes vs. O'Neill Habitats

I checked Kokh's 100 square mile "O'Neill Unit" with O'Neill's figures in **The High Frontier**. He claims an Island Three habitat, 20 miles long and 4 miles in diameter, would have 500 square miles of land area. Each of the three "valleys" in the interior would be 20 miles long by 2 miles wide, or 40 square miles. Three of these totals 120 square miles. Total cylinder interior surface area (including windows) is 251 square miles, while endcaps area equals a sphere of radius 2 miles, or 50 square miles. The remaining 199 square miles must be made up by numerous small "agricultural modules" outside of the main habitat, in O'Neill's total design. But for convenience in figuring, 100 square miles is very roughly correct for the popular conception of the "valley" areas in an Island Three habitat.

Lavatube Remote Mapping

On "Remote Mapping of Lunar Lavatubes," Tom Billings' paper "Radar Remote Sensing of Lunar Lavatubes from Earth" was published in **the Journal of the British Interplanetary Society**, Vol. 44 pp. 255–256, 1991. A more inclusive treatment of "Lavatube Remote Sensing" was given to a seminar sponsored by the Lunar and Planetary Institute in 1992. In regard to side-looking infrared, the detection of a lavatube temperature signature would, we think, be easier during lunar night, when the exposed surface temperature reaches -240°F . The comparatively "warm" -4°F lavatube interior would then be virtually the only "warm spots" on the volcanically inactive Moon. During lunar day, it would probably be harder to differentiate cave interior temperatures from normally shadowed areas on the surface. Such an investigation would have the serendipitous (or even primary) effect of finding any volcanic "hot spots" that may be expressed at the surface (there are indications of a few areas of recent lunar volcanism). Such areas would be mineralogically (= resources) interesting.

Kokh's articles about lunar lavatube habitats and environmental manipulation were right on the money. Beside our own work on these topics, including a study performed for Lockheed, another researcher who has given some thought to lunar lavatube habitats is Andrew Daga, <Daga1@aol.com>.

In all some very inclusive articles, "in depth" coverage of lavatubes, as it were, most welcome and well done. Thank you, Peter!

Bryce Walden, <BWalden@aol.com> Oregon Moonbase, P.O. Box 86, Oregon City, OR 97045-0007



steps
on the Moon
& other leavings

FOOTSTEPS ON THE MOON & OTHER LEAVINGS

Relics of the "Scouting Period" will all be preserved as a part of on site Lunar Frontier National Parks and Monuments or placed in Future Lunar Frontier Settlement Museums.

By Peter Kokh

One frequently hears complaints that we have already "trashed the Moon" referring to equipment and equipment packaging and other items left behind on the Moon by the Apollo explorers. The speaker silently assumes we will never return to establish a permanent presence on the Moon, that there can be no useful function of such leavings, that they serve only as pocks of litter. Since this set of assumptions is without justification, it does more to discredit those who parrot the chant than anyone else.

"One man's trash is another man's treasure" is an even more common tidbit of popular wisdom, however, and happily one that is definitely more applicable to the situation. "When", not "if", we someday return to the Moon "to stay" and make it "Earth's Eight Continent" and the first of many human adopted home worlds, such items, from derelict space craft stages to scientific instruments to packaging waste to footprints – these will all suddenly become invaluable. They will be priceless "hope chest" contributions to future lunar frontier museums and monuments to the watershed epoch of early human and robotic exploration of the Moon..

Even if, to our great shame and discredit as a sapient race, we fail to use our talents and resources to expand into the human hinterland of Greater Earth as we have into all the other companion continents of our native Africa, the contention that these relics of exploration constitute "trash" exposes an indefensible view of man as something apart from, not part of nature. Rather we should have humble pride in these leavings. They are indeed venerable and admirable relics of great achievement and of the enormous capacities with which man has been endowed.

What we have left behind on the Moon is indeed "a promise", a promise to return, to return and stay, a humble engagement token, a sign of betrothal. Even should this future hoped for mutually adoptive relationship with the Moon not develop, these things will still stand long after the rest of human civilization on Earth has crumbled into dust, as mute testimony to the glorious design of Homo Sapiens and the Creative Agency(ies) that led to our emergence. — whether some scouting explorers of other separately arisen intelligent populations ever stumble upon them and feel the wonder – or not.

There has long been deep discussion of future political and economic regimes for the Moon, and on the question of property rights. However these thorny questions resolve themselves, and we have strong opinions on how they should) some very important, and arguably less controversial, legal questions are going unaddressed. Addressing them now could create a momentum of achievement that might help break the paralyzing logjam of endless debate over the other more disputed issues.

For example, we might now set up definitions, standards, and procedures for declaration of various sites and areas of the lunar surface as the lunar equivalent of national parks, national monuments, national scientific preserves etc. Procedures for nominating a site, for establishment of the special status, and for amending that status in the future are needed. At this date when evidence for a case of objection cannot be maturely prepared (e.g. unique geochemical resources of critical economic value) candidate sites could remain simply "nominees". Protocols for the establishment of economic concessions that do not infringe on the scenic or geological rationales for the nomination, could be decided upon now, subject to revision as the on site learning experience unfolds. Might it not be unreasonable to expect that solving these "special" cases will help point the way to acceptable "general" solutions of the property question?

In addition to such special treatment of nominated areas of special scenic and/or geological interest, the historic sites of early lunar robotic and human exploration should be included. In each case, the immediate site could be handled as an easement, with use and encroachment restrictions passed on to whatever future jurisdiction or public, private, or commercial title as may come to be established.

These sites are just what we have labeled them, "hope chest" items for the future edification and education of lunar pioneers, settlers, and visitors to come. They need to be treated, individually and as

a class, with honor, respect, and awe. Popular, if not universal contempt, should be approached as an opportunity for education and public outreach. When and where attitudes cannot be changed, we must sadly learn to dismiss them: "consider the source."

These remarks are meant to address similar human/robotic "tracks and droppings" on Mars and elsewhere. These things will become the foundation of lore and legend. They will live on, their thoughtless denigrators passing from the scene into oblivion.

As human sites, the Apollo sites need special protection and handling. But even robotic sites are instances of virtual human presence and need attention too. It is not too early to discuss proposals for proper preservation and protection. Some of these sites will become enucleating centers of future human settlement. Others will affect the routing of future highways. Their places on the map are more than footnotes to be sure.

MMM

MMM #107 - July 1997

As the Earth Turns ...



Earth: Color Medley Calendar in the Moon's Nearside Sky

By Peter Kokh

[Astronaut quotes below were passed on to us by Cynthia Griffin, Space Research Associates, and are from remarks they made to an audience of military personnel and civilians at the May '97 National Museum of Naval Aviation's annual symposium]

In "Seven Wonders of the Moon" [MMM #69, OCT. '93, p. 8] the view of Earth, hanging there perpetually in the Nearside Sky was listed as one of them. We billed it as "an apparition in the lunar nearside heavens with 3 1/2 times the breadth, blocking out 13 times as much of the starry skies, and shining with 60 times as much glaring brilliance as does the Moon as seen from Earth — all in a spinning ever changing marbled riot of blues, greens, browns, and whites."

Earth as Clock and Calendar

Earth-in-the-sky will offer future Lunans endless fascination as well as a psychological anchor (for better or for worse) for their morale. More on these benefits later. First we want to outline how Earth offers clues to (a) the time of the lunar month or "sunth" as we've more aptly named it, (b) the time of [calendar] day or date, and (c) the time of the year.

TIME OF SUNTH: Earth-in-the-lunar-sky goes through the same series of sunlit, night-darkened phases as does the Moon in our skies — with some spectacular differences. "New Earth" when eclipsing the Sun during what the Earthbound interpret as a Lunar Eclipse will appear as a dark circle in the heavens crowned with the fiery ring of the sunset-sunrise line as sunlight scatters in the dust of Earth's atmosphere. At this and other times, the night-darkened portion of the globe has become in this century increasingly "star-studded" with the city lights of burgeoning urban areas as well as oil and gas field burnoffs of "waste" natural gas and hydrogen. Meanwhile the frequent reflection of the Sun off ocean and ice accentuates the sunlit portions.

The point, not to wander in wonder, is that New Earth corresponds to Full Moon (the entire Nearside hemisphere in dayspan); First Crescent Earth to the waning Moon (nightspace advancing from the east over Mare Crisium etc.); First Quarter or "Half Earth" to nightspace having advanced to the central meridian of Nearside, dayspan advancing to the central meridian of Farside, etc. In other words, as seen from each other's surfaces, the phases of the Earth and of the Moon are opposite. In practical terms, the lunar nearsider will be able to deduce from the Earth's "phase" what is his local "time of the sunth": just after local daybreak, dayspan morning, dayspan afternoon, etc. Of course this will differ according to where the viewer is on the nearside (i.e. at which meridian).

TIME OF DAY (DATE):

While the Moon keeps the same face turned toward Earth at all times, Earth-in-the-Moon's-sky turns on its axis once every 24 hours. Whether the viewer sees the Americas, the Atlantic, Europe & Africa, Asia and the Indian Ocean, or the Pacific as facing him, will tell him what portion of the local 24 hour date it is (distinguishing date from the 14.75 day long dayspan and the 29.53 day long sunth). Depending on how Lunans set up their local calendar and time reckoning rubrics (that is if they do not import unchanged the time reckoning system of Earth), the above concordance may be fixed or it may precess by an hour every 40–41 days if Lunan calendar is set up as I've suggested (so that there are exactly 29.5 days per sunth, rather than 29.5306).

TIME OF YEAR (SEASON):

How the Earth's axis tilts with relation to the Lunan observer at different times of the sunth, will tell him the time of year. The tilt will shift full cycle through the sunth (sequence of phases). If at 1st Half Earth, the north pole tilts toward the right (towards the Sun) it is northern summer, southern winter Ditto at 2nd Half Earth if the tilt is to the left, at New Earth if it is away from the observer, and at Full Earth if it is towards the observer, and so on.

Accompanying the tilt will be confirming visual clues: snow cover in higher Northern latitudes or in higher Southern latitudes corresponding to that hemisphere's winter, the other hemisphere's summer, and so on. Yellow-oranges replacing green shades in temperate zone forests will indicate Fall in that hemisphere, Spring in the other hemisphere. More seasoned observers will be able to recognize seasonal clues in between to give a better approximation.

Pattern Watching

On the ball Lunans will be able to look up at Earth and tell the time of day (date), a close approximation of the date of the sunth (month), and which sunth/month of the year it is — all at a glance. It is the spectacle of Earth, however, that will turn that glance into a lingering observation, the seer into a transfixed looker. While Earthbound students can patiently study an all but changeless Moon, lunar settlers and visitors looking up at Earth will have an unending drama of riveting kaleidoscopic change to admire and study. It will be a treat without the distraction of flora and fauna and weather in the foreground, a Van Goghish canvas of color understatedly matted by black sky and gray regolith.

The first impression will be of ever changing cloud patterns; of hurricanes, cyclones, and typhoons; of storm fronts. Playing hide and seek with the shifting clouds will be the blues of the oceans and lakes and seas, the greens of grasslands and forests, the light tans of the deserts, and the glaring white of snow and ice. Beyond the day/night terminator, again playing hide and seek with the clouds, will be a light show extraordinaire: lightning and forest fires on the natural side, city lights and oil and gas burnoffs added by man. Different observers will see and watch for different things, each according to his/her own interests. Some will habitually count lightning strikes, jotting numbers in a log. Others will try to catch a glimpse of the light patch that locates their hometown lights or the lights of other towns, cities, and urban industrial archipelagoes.

Relatively few sets of elements will contribute to the never repeating sequence of Kaleidoscope treats. Not all the elements will appear with the same frequency: for example, the appearance and track of the approximately 60 mile wide Moon Shadow across the lit face of the Earth during what terrestrials experience as locally very rare Total Solar Eclipses. And the relatively glare-free conditions of solar eclipses (which we experience as eclipses of the Moon), many fainter nightside light glows may become visible to the practiced lunar observer.

“Humansign”: Earth as an Inhabited World

That Earth is an inhabited world will be quite apparent. In the night portions of the observed face we will see the city lights, some unnaturally frequent forest fires, and the oil field gas burnoffs. In the sunlit portion of the Earthglobe we might see some agricultural patterns, and even detect portions of national borders betrayed by differing land use patterns on either side. We'll also see slow changes from advancing deforestation and desertification. Man-made reservoirs will catch the sunlight where once there was all-but-undetected river valley. And we'll spot natural floods that are here and their 'controlled' by man-taken measures. All these signs will be studied acutely by those keenly interested in the great unplanned experiment of environmental “deterraforming”, going on more or less continuously since the invention of slash-and-burn agriculture in Europe some eight thousand years ago.

For those fascinated by Earth's city lights and their identification, an amateur observing league may give out “Edison Certificates” to those who have correctly identified a representative selection of a hundred-some urban concentrations – much like the Messier Certificate Program in which backyard as-

tronomers seek to identify star clusters and nebula on an early and popular list of the brightest such objects. Advanced observers will be on the watch for blackouts, major fires, night launch rocket booster burns as well as fiery nighttime reentries.

For the Earthborn, night lights of homelands and hometowns and spaceport points of departure will hold special interest. For native born Lunans, night objects sought out will include a less predictable list of various places they've each heard and read about, and which have fired their imagination.

Naked eye observation of Earth

Full Earth illuminates moonscapes with sixty-some times as much brilliance as Full Moon brightens Earthscapes. But without a dust and water vapor laden atmosphere on the Moon, Earthside shadows will be inky black and impenetrable. A happy result is that starlight is not drowned out.

Yet not all lunar settlers and visitors will be able to appreciate Earth-in-the-sky with equal ease. To paraphrase the opening sentence in Caesar's report on the Gallic Wars, "All Luna can be divided into four parts".

In the central portions of Nearside, Earth is either directly overhead or at a very uncomfortably high angle above the horizon. We might nickname this central area **The Crooknecks**. It includes most of Mare Imbrium, Mare Nectaris, Mare Serenitatis, Mare Tranquilitatis, Mare Nectaris, Mare Vaporum, etc.

The Postcardlands are the peripheral stretches of nearside, regions in which the Earth hovers perpetually a comfortable 5–40° above the horizon. Adjacent to these, straddling the "limb" of the lunar globe which forever keeps the same side turned towards Earth are **The Peek-a-boos**. As the Moon's axis is not perpendicular to its orbit around Earth and because that orbit is somewhat eccentric and the Moon travels faster when nearer Earth and slower when further away, all the while rotating at a fixed rate, about 7° to either side of the 90° East and 90° West lines are alternately turned towards Earth and away from Earth, psychologically annexing about 9% of "Farside" to Nearside.

Together the above three regions cover 59% of the Moonglobe. The remaining 41% might be dubbed **the Obliviside**, the Farside heartland from which Earth is never visible – and as the old saying goes, "out of sight, out of mind."

Special Observing Equipment

Special equipment will not, without signal relay, make it possible for deep Farsiders to observe the Earth. But in Greater Nearside, if we might call it that, many of those enthralled by the sight of Earth will be motivated to go beyond Earth-facing picture window portholes in their shielded abodes.

Oculars and binoculars will be among the simplest terrascopic assists, along with large Fresnel lenses or projection lenses in front of windows, much as late 40s/early 50s small screen TVs used similar fore screens to magnify the view. Special amateur optical telescopes designed with the aperture above the surface, but the observer eyepiece optics within the pressurized habitat for direct shirtsleeve observation will be popular with purists.

But for others, HDTV monitors, interactively zooming in on selected portions of the Earthglobe, will provide even better views. There might even be a dedicated fully interactive yet live Earth View Channel offering not only spectacular live detail, but also multi-spectral false color enhanced imaging that cues in on ultraviolet, infrared and other cues in the more complete light spectrum. Various interactive programs may search on demand for lightning flashes, pick out keyed in cities or other locations, even overprint city names of areas on which the viewer has focused in. Instead of the view from the Moon, auxiliary channels could give the view from LEO and GEO satellites, or even from future flank observation outposts in L4 and L5.

As on Earth, some avid observers will be heavily into photography, others into interpretive drawings, and yet others into raw and immediate unfiltered live observation. Yet glare reducers and variable masks for night side viewing will be standard (and the automatic default setting on TV).

Earthsight as an Umbilical Fix

The riveting sight of Earth will be the chief anchor with 'reality' and with the heritage of their individual pasts for the early Lunan pioneers.

``Landing on the Moon was not nearly as overpowering and as memorable as just going to the Moon and looking back at Earth. We went to explore the Moon, and in fact discovered the Earth."

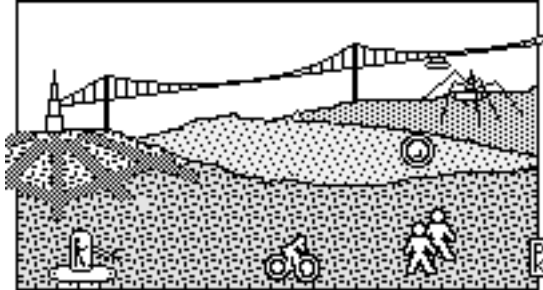
— Eugene Cernan.

Looking out the Apollo Module porthole from out around the Moon, Apollo 8 and 13 astronaut James A. Lovell, looking back at Earth, was able to block it out with his thumb. Later he recounted, "Everything that I ever knew – my life, my loved ones, the Navy – everything, the whole world was behind my thumb."

One can argue if this is good or bad. Deep Farsiders may tease Nearsiders about their mommy-fixation to Old Earth, boasting of a keener, deeper openness to the Universe at large, and of a greater space-hardiness that results.

We'll see. <MMM>

MMM #111 – December 1997



Out on the Lunar Surface

This month, we take an outdoors, or out-vac perspective on the lunar settlement. Our first feature article takes a second look at the possibility of "skyscrapers" out on the open – not under some fairy dome (for first article see MMM # 55). In our second feature article we explore the various ways the true outdoorsman (who will have given up so much on forsaking the "Green Hills of Earth") might be able to satisfy the urge to be actively one with nature.

Lunar Sky scrapers Shattering Low Expectations

By Peter Kokh

[see MMM # 55 MAY '92, pp. 5–6,

"SKYSCRAPERS on the Moon? Beyond Mole Hill City"]

An envelope-bursting topic revisited

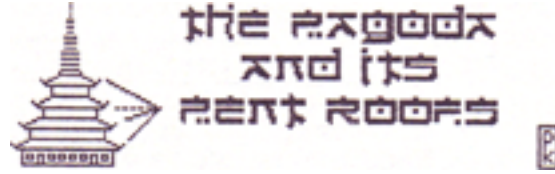
The conventional wisdom is that surface-embedded or surface-burrowing lunar settlements will be monotonous complexes of "mole hills" unrelieved except by docking ports, communications antennae and other systems hardware that must be on the surface or surface-exposed. Yes, we have all seen science fiction artist renderings of skyscraper studded lunar and Martian cities on great glass domes. But that is an eventuality for realization somewhat further down the road, if ever. And as to settlements within lunar lavatubes, some with ceiling heights a thousand feet high or more, – why, what we'll have there, are ceiling-scrappers (or even ceiling-touchers). In both these cases within pressurized megas-structures, the first manmade, the second provided by nature, the skyscrapers are likely to be conventional copies of what is current construction structure and form on Earth.

But what excited me when I wrote the first article five and a half years ago, was the realization that the starter premise just wasn't necessarily true. We could build fully shielded "skyscrapers" to centralize the downtowns of lunar settlements built the way settlements on Old Earth always have been, the old fashioned way, one structure at a time.

The "Pent Roof" makes it possible

Egyptian pyramids, Mesopotamian ziggurats, and the Tower of Babel notwithstanding, the practical skyscraper was an urban innovation that awaited two inventions: the steel girder, and more importantly, the first people mover – the elevator. (Yes we know the Russians have built high rises without elevators, so, what's your point?)

For anyone imagining a lunar surface settlement cozily tucked under its regolith security blanket for protection from the local cosmic weather and for thermal averaging, the idea of a skyscraper-studded "downtown" just did not occur. How would you shield something like that?



Enter by happenstance, a picture of a Chinese pagoda in some book I was perusing, and a eureka brainstorming avalanche was on its way cascading down the brainslopes of my mind.

A little redesign slight of hand with those pent roofs (pent as in penthouse), and they could serve as overhanging retainers that could hold a couple of meters of lunar regolith shielding – not prohibitively heavy in the light lunar "sixth-weight."

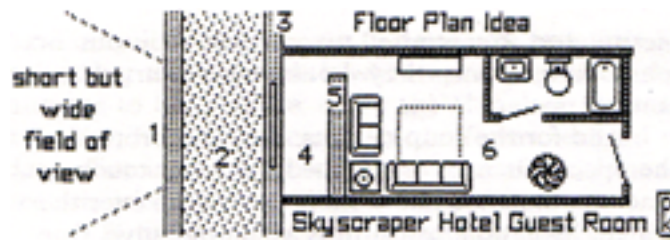


For people on the Moon for long duration or indefinite stays, it is important to be very, very conservative in minimizing accumulative radiation exposure. "Windows" providing the satisfaction of regular views out onto the local moonscape should incorporate broken pathways, using mirrors, so that the observer is protected in every direction by adequate shielding, so that the habitat or moon manor has not "hot spots". The same is true of any type of structure in which people regularly work or spend significant accumulative time.

In comparison, the "pent roof" balcony overhangs would provide safely set back vertically narrow eye level slit windows, and through them, horizontally constrained views of the moonscape. Looking out through one of these, the observer would see just enough "sky" to frame the view, a sky with very few square degrees of exposure to the naked cosmic heavens and its hot delights.

If you wanted to build a pentroofed office building, you would have to tweak the internal layout so that the interior space sporting these view ports was reserved for use principally by visitors, and, compromisingly, for regular office personnel and daily maintenance staff people "on break". The principal break room and lounge areas, however, would be in interior parts of the building that did not sport such direct-view windows). In other words, lunar office towers would have such slit windows only here or there. The architect could always resort to rows of fake trompe l'oeil windows to create the right external effect. After all, the architect has two goals in mind: an optimum, occupant user-friendly interior arrangement, with a full suite of desirable function areas; and, a pleasing, readily identified, and positive image-creating external appearance on display for the potential using public passing by.

Such pent roof windows might be used with more abandon in buildings more heavily used by visitors, such as the Luna City Hotel. Even so, for the protection of guest room cleaning staff especially, the architect would want to tweak the internal room layout to minimize the total accumulative fraction of daily time spent in the hot spot pools of naked sky exposure. And hotel management will be constrained by law to rotate staff duties to minimize the chances of anyone getting too much accumulative exposure.



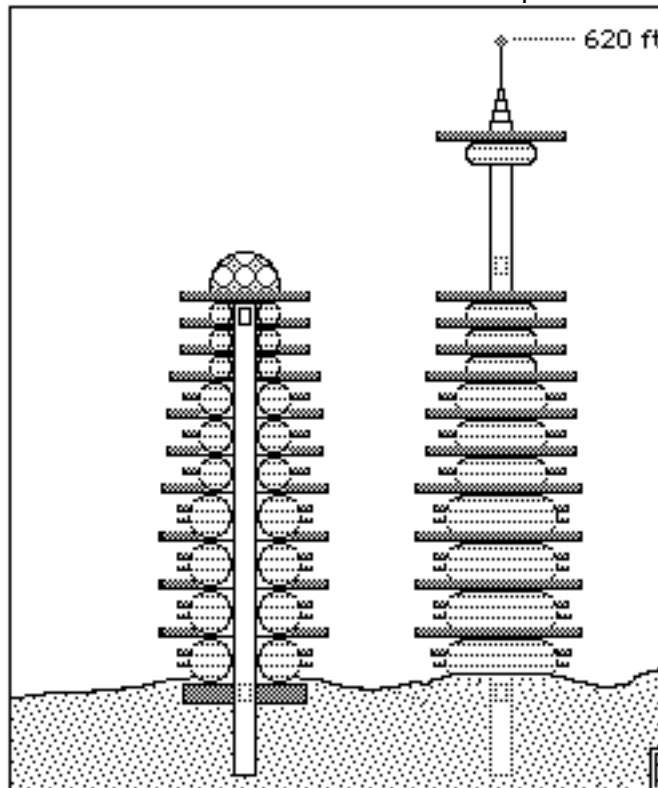
KEY: (1) Outer retaining wall of pent roof; (2) shielding;
 (3) "Hull" wall of Hotel, with narrow, high, window slit;
 (4) Interior, shielded, viewing "balcony"; (5) an interior "shielding partition"; (6) Guest Room proper

A Second Look

In that article we looked at three possibilities: (a) single or multiple vertical cylinders with pagoda like pentroof balconies holding shielding mass, yet which allowed vertically narrow views of the surroundings; (b) Stagger-stacked horizontal cylinders, again with pentroof shielded and windows; (c) a circular pyramid of horizontal cylinder sections of decreasing diameters.

In retrospect, this last design option seems the most strained. Pressurization stresses would make it the most likely to fail. This article offers a radical rethinking of the round pyramid format.

Instead of stacked cylinder sections of decreasing diameter, we now propose stacked torus units of decreasing outer diameter, but of set inner diameter (of the donut hole). And they would be stacked over and around a vertical cylinder which would carry the elevator shaft and service chases for electricity, communications, thermal control, and. If this seems reminiscent of a popular children's building block toy, it is with reason. Here lies the humble source of our inspiration.



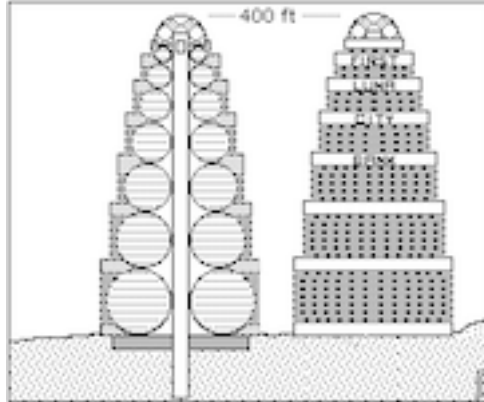
KEY: (left) see-thru observation dome skyscraper (right) outside view of twin tower with revolving restaurant. Both have 23 occupiable floors.

In the design shown above, for illustration purposes only, the upper torus tier would be sized to include floor to ceiling clearance for one floor, The next tier, two floors, the bottom tier three floors. The exposed roof overhang of each torus would be covered with shielding, pentroof style, as illustrated in the previous article, partial pent balconies at each intermediate floor level. Not a very visually pleasing design, however structurally sound.

One possible building top embellishment is a geodesic dome or hydrosield dome (a Marshall Savage idea) serving as an observation area, the later much better shielded. Another obvious topper option is a service core shaft extension to a revolving rooftop restaurant, à la the Space Needle in Seattle (just the first of many copycat structures now highlighting downtown skylines around the world). With possible structures like these, the analogy of the downtown centered Earth city is wonderfully translated into the construction idiom of incrementally growing regolith blanket shielded lunar, or Martian, surface settlements. Marketable uses are for bank office buildings, corporate headquarters, and hotels.

From Pent Roof To Caisson

The illustration effort above yielded rather ugly results. The important thing about the torus – central shaft stack is its dynamic stability pressurization-wise. Why not, for this application, shuck the pent roofs for cylindrical caisson sections holding shielding up against the building. These bulkheads would not be pressurized and can be vertically flat.



This results in a much more conventional look. These are some ideas thrown out for improvement. We'd like to see now good artist renderings of a downtown-centered lunar urban panorama.

<MMM>

Opportunities on the Moon for the Incurable Outdoorsman

By Peter Kokh

What's a Field & Stream sort of guy to do on a world where you need a clumsy spacesuit just to survive?

A Truth-in-Writing Declaration

The author is not a hunter or a fisherman, nor a sailor or pilot. Nonetheless, he loves the outdoors with a passion, finding exhilaration and renewal in long walks through woods and fields. up mountain-slopes and through rocky canyons, either by himself or with his dogs. Through the years he has had many a treasured moment sitting alone by a well hidden waterfall, or perched on some mountain peak looking down on valleys, yes, down even on clouds and eagles. Yet this has been sporadic activity for him, and he knows full well that there are those for whom the outdoors is not just a shot in the arm, but lifeblood.

Just the facts, Mam

The Moon has no atmosphere. You cannot stand outdoors in your shirtsleeves, not even bundled up but with face exposed, enjoying the uninterrupted sunshine, or the star spangled skies beyond belief. You must wear a spacesuit, or be in side a protective vehicle, or within a pressurized structure. Your communion with nature cannot be immediate, as on Earth. It must be mediated, very unsatisfactorily, by contrivances and contraptions allowing you to survive outside of your element.

While there is no air or breeze to be chilly or sultry, surface temperatures can swing wildly between sun and shade, between dayspan and nightspan. Exercise and exertion mean a buildup of heat from which it is difficult to find relief. Sweating only makes things worse, steamy in the sun, clammy in the shade.

Outdoor sports like flying and soaring and kiting and hang-gliding are not possible. Though human-powered flight may become a commonplace in large enough pressurized mega-structures. Fishing and hunting will be possible someday, but only in small captive reserves, smacking of "canned

hunting." Swimming needs only an indoor or middoor pool, and canoe-ing along urban canals and boulevard streams is a likely target for city fathers seeking to make life as homelike as possible. But open sea sailing and boating will be a memory, or at best a virtual reality pastime.

For the spelunker, there will be lavatubes aplenty. But these great lunar underworlds, unlike Earth's limestone caves carved by water through sedimentary rock that once was ocean bed, lack stalactite and stalagmite, no curtain, column or drapery formations; they boast no underground streams or pools.

And for the coup de gras, even the protection of the spacesuit is overwhelmed by time, too long out-vac at a time, too many short excursions over the long haul. Radiation expo-sure is accumulative. One will have to hoard his surface outing time, saving it for occasions that are the most necessary, and/or the most rewarding. No all day, every day stuff. Never again for those who would forsake Cradle Earth. Not until another sweet thick atmosphere blessed home world is found, or made.

What's a guy to do? no green hills or valleys, no woods, no grassy plains or meadows, no boundless seas horizon to horizon!

Quit your bellyaching!

The Joe Six Pack, who only imagines himself indulging in all these activities from the safety of his sofa cushion, will moan and groan. But the true inveterate son of the outdoors will find a way, make a way if necessary, to satisfy his search to live one with nature, one with the wind, one with the sun, one with the stars. At least on the Moon, it is possible. Those who boast that they are nature's children, but only indulge themselves from the safety of a tether-leash, in urban parks and man-made meadows, will delight, poor souls, in those human "zoo-parks in the sky", the great O'Neillian space settlements. Some of us must march to another drum. We need to be one on one with nature, and not just nature counterfeited by man – in a bottle.

Here on that harsher frontier, where there are natural landscapes and land forms undreamt of, where one is surrounded by nature untamed and uncaricatured by man, the true outdoorsman will find a way, indeed many a way. And the result will be all the more gratifying for the challenges that will have been overcome along the way.

The Spacesuit is dead! – Long live the Spacesuit!

The spacesuit has its origin in a series of ad hoc improvements to the high altitude aviator's pressure suit. It has been made capable of handling not just thin air, but vacuum, not just cool or warm air but the merciless heat of the unmediated sun, and the insatiable heat sink of the naked cosmic skies. In the process it has grown ever heavier to wear, ever more cumbersome to move around in, or do useful tool-yielding physical work. Using it to transfer between pressurized habitats or vehicle cabins and the vacuum out side requires expensive airlocks, poor at retaining precious volatiles, and failing altogether to keep outvac the insidious, mischievous, ubiquitous moondust.

The spacesuit needs to be rethought. The time is long overdue. But you don't see the need if you have only short term goals. It is perhaps imagined by many that the spacesuit is what makes it possible for humans to be in space, or on the Moon, or Mars. In actuality, it is the spacesuit, in the forms realized to date, that is the biggest onsite obstacle to human acculturation to these alien shores.

First, routine chores outside pressurized habitats, outposts, and vehicles, can be performed much more comfortably in the older more flexible less weighty high pressure aviation suits. All we need to do is to put in place sky/sun shielding ramada canopies over routine work areas and aprons.

Second, the space suit can be radically redesigned to be entered as if it were a formfitting vehicle, from a turtleback life support unit. One backs into a conformal convex dock-lock, the turtle back engages, the inner hatch opens, the turtle back opens into the interior space thus opened up, and the suit wearer reaches up and out behind his head to grasp a bar inside the habitat or vehicle and pulls himself out of the docked suit, into the habitat or vehicle. There would be much less precious volatile loss (specifically Nitrogen) during each outbound cycling, much less insidious moondust tracking in on each inbound use. [see MMM # 89 OCT '90, "Dust Control"]

Today's suits are veritable "Dagwood sandwiches" of layer after layer of different materials, chosen to hold in the pressure, keep out the vacuum, and buffer against thermal extremes. The result is an unwieldy amount of bulk that makes motion difficult, and the graceful agility prized by the outdoorsman, nothing more than a forgotten memory. Are there alternatives to this overbearing layering? Maybe not, but the "Young Turk", the won't-take-anyone's-word-for-it type of guy who in the end invents

everything, will be the one to test the uprightness of this all too early capitulation. One almost suspects that the greater the perceived technological difficulty the more likely "ordinary folk" will continue to leave space, and the Moon, to the godly experts. It is important to the priestly class who now permits only token human scout activity, to maintain all myths.

Assume a lighter suit, one that is entered through a docked turtle back hatch, rather than donned inside in preparation for a ceremonialized grand exit or entrance through the airlock. Given such substantial improvements, personal after-breakfast or after-supper hikes through the never quite the same moonscapes becomes a possibility.

In his novel **Earthlight**, Arthur C. Clarke has his hero jog some 600 kilometers to the nearest outpost after his vehicle breaks down. Not bearing all that weight. Not without being able to shed all that perspiration and heat from exertion. In high sun conditions (say within 20° of the equator, and within two days of local dayspan noon) solar overheating can be avoided by deploying a gossamer helmet mounted parasol of aluminum foil. In sixthweight and in the absence of air and wind, such a comically ungainly contraption will be less ridiculous than it seems.

In the all time number one science fiction best selling classic *Dune*, the desert dwelling Fremen wore stillsuits to both conserve body moisture – even the urine was recycled into drinking water – and shed excess heat. This fictional concept provides a goal for those who would improve the spacesuit to strive after. It is those who would not try, and don't want to be proven wrong, who say it can't be done.

The Buppet

The Buppet, like the turtle back suit, is something we've spoken of previously, for instance in the "Dust Control" article cited above. The Buppet (contraction of Body Puppet) is really a telephone booth sized upright personal cab(in) within which the shirt-sleeved operator directly controls manipulator arms and either "legs", tracks, or wheels. This device will allow a more immediate sense of oneness with the terrain than that afforded by vehicles of more conventional configuration. What's more, it is made for one, and will take you where you want to go in acceptable comfort. Ideal if you are a prospector, like to collect rocks, or simply explore difficult but scenic terrain. It will do fine, with inboard stereo, to just loose your-self over the horizon for a while, meditating on all the mysterious meanings and enigmas of life.

From Personal Vehicles to Motor Coaches

Your spirit of adventure may be well-enough satisfied by following sundry beaten tracks. Or it may compel you to seek the trackless expanses "where no man has gone before" or at least not too often. You know yourself. In the first case, just the right personal vehicle for you may be relatively small and simple. In the second case, you may need prudent capacity for provisions, spare parts, tools, and medical supplies, as well as a vehicle with a much more capable suspension and life support system. If you are not one to stray far from home, but like to get out on your Harley all-terrain moon-bike once and awhile, there probably will be just such a bike for you. [Herein Milwaukee, where Harleys are made and designed only a few blocks from my home, we had hoped to coax Harley-Davidson into putting together just such a dustmaster for ISDC '98. Alas, we let our lead time slip, and it's not to be.]

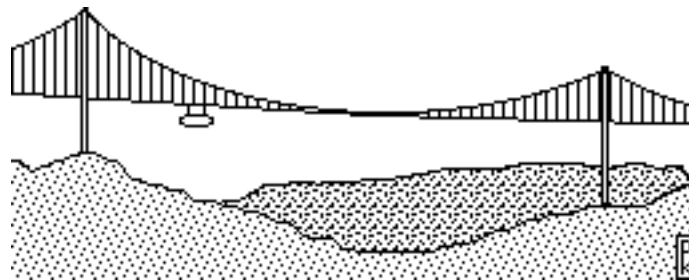
For the everyday intersettlement traveler or businessmen, the first modest coaches operated by Graymaster Lines, may be conversions of the crew cabins of "amphibious" lunar landers. Such vehicles which we have dubbed frogs, or toads (depending upon whether the conversion is temporary or permanent) would have the crew compartment, equipped with a wheeled and motorized chassis, underslung between the engines, so that upon landing, they can be winched down to the ground and taxi away.

So what's an Outdoorsman to do?

Well, if you can live within the Rad limits, without cheating by removing your monitor wristband either occasionally or with compulsive frequency (until and unless you have been diagnosed with an incurable fatal or degenerative disease – why, then, reckless is the thing to be!) – if you can live within these strictures, and be satisfied, you can do a lot. Personal motor-exploring, occasional suited sorties to reach some near-path scenic overlook or vantage point. You can tell at a glance if you are the first to visit a site, or one of the few.

- **Motor rallies** with others and against a clock
- **Motor races** over prescribed routes
- **Rock collecting** and for-fun prospecting, always with the eye open for something rare and unusual and hopefully important

- **Exploring near-surface and deeper lavatubes**, many of which will play host to major settlement and industrial activity, as the Moon's most benign potential "habitats", the only (Nature-) improved real estate on the Moon
- **Soar over the surface in lunar hoppers**, and over great stretches of the globe in lunar suborbital transports



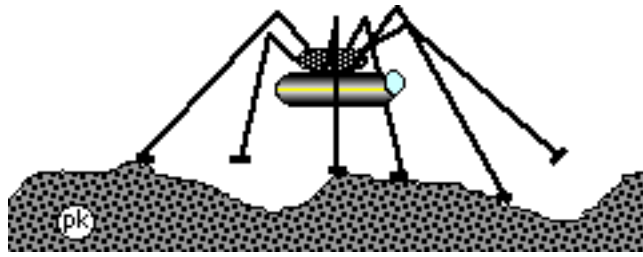
- **Cruise long distance** just over the surface, enjoying bird's eye views at a relaxed pace from a suspended cableway.
- **Enjoy the scenery** in smoother, swifter fashion in intersettlement Mag-Lev vehicles and trains
- **Enjoy Earthset and Earthrise**, and in between, the unimagined glory burst of the Milky Way from the lunar limbs, the peek-a-boo lands that alternate between nearside and farside
- **Enjoy some incredible scenery** from rille tops and crater crests, with the ever-changing patterns of inky black and dazzling gray-whites – the jaded will say so unsuspectingly "seen one crater, seen 'em all!" It's their loss, keeps the traffic down
- **Visit a clear glass-composite enclosed waterfall** and cascade down the inner slopes of some deep crater, part of a hydroelectric nightspan energy plan in which solar energy pumps excess water up the rille or crater slope during dayspan, to let it fall through turbines during nightspan
- **Enjoy an evening campfire** with a special fuel cell that uses an enclosed flame to combine oxygen and hydrogen to make drinking water



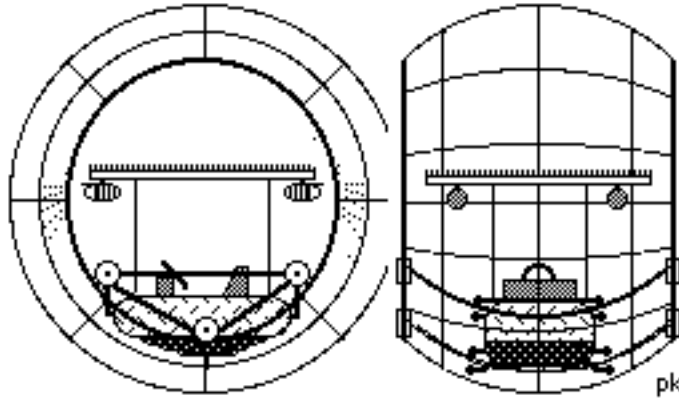
- **Enjoy pressurized out-on-the-surface amusement park rides** in giant roller coasters, accelerating slowly but without air and wind to put a limit on top speed, perhaps down crater ramparts thousands of feet high, maybe plunging into a shed tunnel near the crater bottom in pitch darkness, before emerging on the braking coast out onto the reassuring sun-baked surface.



- **Roll over the undulating terrain in "unitrack" squirrel cage "atlas balls"** in which your seat rides an inner circular upright track within the ball-frame, well below the center of gravity. Work your geodesic cage along a rally course of crater-lets etc. Solar powered, the spheres would have a track riding buggy capable of generous side-to-side movement or banking – call it a unicycle, an auto-tracker, a cyclotrack, or whatever.
- **Scamper over rough terrain like a giant spider**, in fact within a spider leg suspended cabin with great views. {MMM # 81 Ibid. p. 7 "Go Anywhere"}

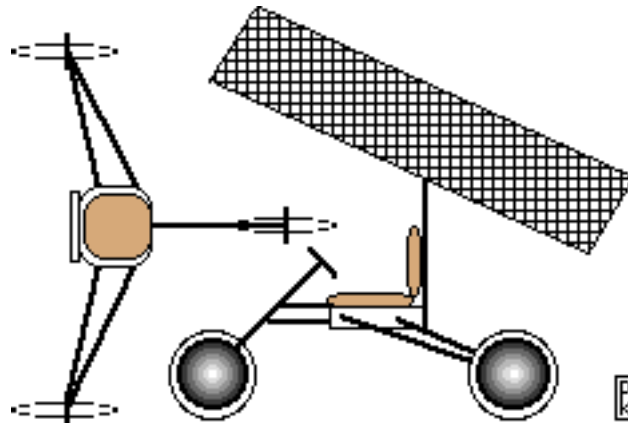


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[MMM #81 DEC '94 p1 "Surrey with a Fringe On Top"]

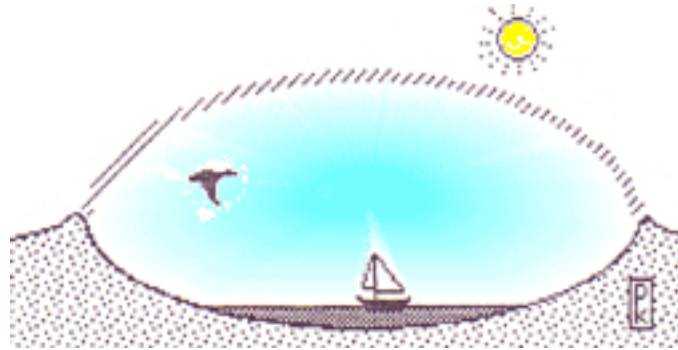
- **Sail across the long congealed lava "Seas" of the Moon** in electric powered lightweight moon-dust outrigger trikes driven by solar energy, your spacesuit serving as cabin.



- **Bungee jump with your spacesuit on**, of course, from a bridge or cable car suspended over a rille or large crater
- **Do a duty tour with the Frontier Authority's road, bridge, and cut building crews** as a volunteer or as a court assignee (in lieu of jail)
- **Serve on exploratory / prospecting excursions** or new town site preparation
- **Get a job at the settlement space port yards**, or driving a Graymaster intersettlement coach, or over the road rig
- **Get a job as a technician** in repair, maintenance, instrumentation changeouts at a remote optical or radio observatory.

Farther Down the Road, Way Down

- **Fly again, go sailing and boating again**, in a crater miles across, covered over with a glass-composite enclosed "hydroshield" dome-vault, à la Marshall Savage ("The Millennium Project") to create a spacious Earth-like Oasis on the Moon. Such a hydroshield will supposedly let in light and moderates temperatures.



- **Ski, or toboggan**, in your spacesuit with a break resistant visor and tear/ puncture resistant fabric, down a high mountain-slope covered with silicon powder (if only silicon were a true analog of carbon and we could have silicon buckyballs!)
- **Go hiking, photo-hunting, picnicking, camping** in a many miles long meandering rille valley, vaulted over and pressurized and transformed over decades into the first lunar National Parkway and Nature Preserve.



And so?

We have included in the outdoor menu above recreational, hobby, leisure travel, and occupational activities that outdoor lovers from Earth might enjoy in the "magnificent desolation" of the Moon, provided they have an open attitude. Temperaments and moods firmed up by stubbornness are not easily changed. But then we are speaking to outdoor souls.

It will never be "just like on Earth," You can't substitute for Earth's forests and plains, for its rivers and lakes, and least of all for its global ocean, the mother biome of all life. But if the pioneer ceases to pine for what he or she has willingly left behind, and give it a chance, there may lie ahead plenty of moments of outvac satisfaction. The Moon is not Earth, but it has its own beauty, its own scenic wonders, its own awesome sights. In this now alien environment, people with "outdoor souls" will someday come to feel quite at home. They will learn to love activities they can indulge in on the Moon but could never do on Earth.

The Moon offers vacuum, lavatubes that are gargantuan by Earth standards, awesome craters and vast frozen lava flood plains. It offers stunning views of Earth, and the stars? Why Lunans will wonder how people of Earth could ever have been drawn on an epic journey to the stars that they could barely see. And hopefully, any sense of loss that lingers in first generation pioneers will sublimate into a drive, a passion to find still more ways to enjoy, relax, and have fun in the great outvac.

In the end, the prospective pioneer must choose. If there are activities on Earth that cannot soon enough be duplicated on the Moon, to which his happiness is pegged, it's best to be honest and call your self a stay-at-home Pioneer supporter. There is no point in being heroic. There is nothing wrong with being attached to recreational pursuits than will not translate well to the "new" world. The Space Frontier needs not only those willing to and psychologically capable of forsaking Earth, it needs real trusted friends who will stay at home and lend invaluable support that can only be given by people in the mother world.

<MMM>

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

A. Gide

The Out-Vac Sculptor

By Peter Kokh

Human acculturation to the Moon involves more than just using lunar materials to build with and express ourselves creatively within tight-hulled minibiosphere settlements. There is no need to confine the material evidences of human interfacing with the Moon within “reservation” “ghettos”. We will also build roads, roadside inns, solar flare sheds, repair garages, outfitting supply general stores, and so on, in between settlements. We will build scenic overlooks along crater rims and other high points. There will be rural retreat houses, and small rural “intentional communities” or communes (we’ve suggested the name “tarn” from the Old Norse for a small mountain lake in its own isolated mini-basin or cirque – after all, such rural outposts are isolated oases with their own water reserves.)

Over and above all this, it will be legitimate for Lunan artists to express themselves creatively in the wide open spaces of the out-vac in a way which both complements its “magnificent desolation” and which also celebrates the new stepmother-stepchild relationship of Mother Moon and the new frontier human settlements and communities. Out-vac sculptures will proclaim the mutual adoption of both for one another. In many cases such 3-D creations will serve useful functions. Both raw “magnificent desolation” and human artifacts give glory to the Creative Energy at work in the Universe through everything, through each according to its nature.

Available Sculpture Stuffs

Sculpture comes in many forms: carvings, castings, assemblages, and simple arrangements of found items. Different materials can be used or worked in varying ways to form 3-D creations. What lunar available materials might a transplanted sculptor pick for various large-scale out-vac art creations? On hand, usable almost as is are these:

- Boulders, rocks, and breccias (rock composed of angular rock and glass fragments melded together): Large boulders can be used as landscape accents, or, engraved, as milestone markers, sign posts, etc. Smaller rocks can be used as is, or cut into blocks or slabs, even polished. Question: would their surfaces sparkle with fluorescence under black light?
- Simple mold-sintered regolith, in various natural regolith shades perhaps gathered from remote sites to provide enriching contrast with the local soil.
- Sintered mold-shaped low-performance creations of iron fines. These fines are fairly abundant in lunar regolith from which they can be harvested with a magnet. Sintering does not impart great strength, but out-vac sculpture creations which undergo only dayspan/nightspan thermal stresses should endure.
- Iron castings and wrought iron, prior to the availability of steel alloy ingredients might make durable sculpture materials outside rusting atmospheric of settlement interiors. (Items could be steam-rusted in pressurized studio compartments before being placed in permanent out-vac locations as an option if rust color is desirable.)
- Native glass spherules might be used in various surface treatments in sun-catching ways.
- Manufactured glass of various crude to refined formulations: poured, cast, blown, reinforced with clear or colored fiberglass, prisms and colored sun catcher creations; mirrors.
- Cast basalt, a onetime actual industry in Central Europe which could easily be pre-pioneered anew in states like Oregon, Washington, Idaho, Hawaii, etc.
- Ceramic pavers, glazed or unglazed
- Gunite: a mixture of lunar cement, and rough-sifted regolith with glass and small aggregate inclusions, sprayed over forms to create lightweight simulated lunar rock. Terrestrial Gunite™ is used to make lightweight “rock” outcrops in zoos, for example. (may be the standard faux rock in space settlements).
- Cast magnesium (unalloyed, dangerously reactive in oxygen), where we would use bronze on Earth.

- Aluminum, steel, and titanium, once these are produced on the Moon.
- Welded salvage scrap metal and abstract or form-suggestive junkyard creations, using discarded metal objects originally forged on Earth.

Some Out-Vac Applications

Sculptures and sculpted works might be placed in the out-vac for a number of reasons. For the enjoyment of travelers, “sculpture gardens” would provide welcome interest in areas where the native “scenery” is especially monotonous. On Earth, we find sculpture gardens on the grounds of museums and, in some states (e.g. Nebraska) concerned with interrupting soporific driver fatigue, boredom, and mesmerization with the road, at scattered highway waysides. But these are within the given biosphere, enjoyable in “shirtsleeve” comfort, as is everything on Earth. So such use provides no easy parallel on the airless Moon. There, travelers are not going to don individual spacesuits to exit their protective motor-coach or other vehicle just to peruse a bunch of sculptures. Too much hassle.

Like façades of corporate headquarters deliberately sited alongside busy interurban freeways, and meant to be enjoyed in fleeting glimpses, such “freewaytecture” provides a better model. Items in a lunar out-vac “sculpture garden” could be placed in a well-spaced row, say in a “boulevard median”, to be enjoyed in quick glances out their coach windows by people on route from spaceport to settlement gate and vice versa. Deliberate distractions of this sort would seem especially appropriate along stretches with little “competing” natural scenic attraction. The sculptures chosen would have just enough detail to be appreciated on the fly, yet enough to be enjoyed over and over on repeat passings. This generalization would seem to be pertinent for all out-vac sculpture.

Monuments commemorating historic sites (first “overnighting” on the Moon, etc.) and historic events could aptly be set out on the naked surface along well trafficked corridors, aimed at catching the eye just long enough to stir the soul, no more. Of course a monument could be tall enough, and/or set on high enough ground, to be observed with more intent interest for an extended time and for many miles as vehicles approached the site, passed by it, and then receded.

For example, a very large scale sun-catching monument of polished stone, polished aluminum, mirrored glass, clear glass, or prism shape, etc., erected to celebrate the achievement of independence by the Lunan Frontier Republic might be placed atop a mountain peak that stands prominently out from other nearby surface features from well beyond the general horizon. Mt. Piton, an isolated 7,500 ft. high massif in ENE Mare Imbrium is one such example. From atop this perch, a monument such as we’ve described could be seen above the horizon for many tens of miles from a busy road passing to its sunny south between Mare Imbrium and Mare Serenitatis, where it could mesmerize passersby. Such a road could very likely become the busiest east-west travel corridor on the Nearside. (This previously published suggestion is not mine. Ben Bova’s?) Again, freeform and abstract design would work better than anything demanding closer inspection to be fully enjoyed.

Decorative options combine with utilitarian function to provide many other non-commemorative chances for out-vac sculptors to express themselves and delight others. Graded roadways could have their right-of-way edges clearly demarcated by rows of gathered smaller boulders, rocks, and breccias. These could be left natural, art limited to selection and serial arrangement, or they could be cut and polished to better catch headlights during nightspan, or along shadowed stretches during dayspan. This both decorative and utilitarian technique could then be applied to the slopes of road cuts, embankments, and retaining walls as well, which could be covered and/or stabilized with cut rock “pavers”.

Question: certainly some Apollo moon rock researcher has tested both moon dust and various rocks and breccias, intact or cut, for fluorescence in “black light”. [If any reader is familiar with such research, would they please acquaint the editor with the results?] If this fluorescence exists and is high enough, maybe black light headlights would be more appropriate along lunar highways, at least during full nightspan, than normal halogen or other visible light lamps, especially on the farside, out of reach of “Earthlight” (which should provide illumination enough). After all, the roadway is unlikely to hold other obstacles, and if it did, radar, more easily linked to automatic warning or steering correction devices) could more easily and spot these and more accurately access them. On Farside, the use of black-light only would allow drivers and passengers to enjoy the full splendor of the intensely star-spangled lunar heavens.

Early lunar highways, when they come to rille valleys too long in either direction to detour around without major inconvenience, will probably simply angle down one slope and back up the opposite one. Eventually, in high traffic areas, more expensive bridges and causeways may be justified. While

these will be basically utilitarian in their design, there will still be several basic structural design choices, as well as elements of each design not constrained by function. Such elements will provide sculptural and decorative opportunities: side bumper walls, lampposts, mid-bridge scenic turnout markers, etc. Roadside signposts in general (milestones, junction directions, "Place of Business" signage), offer decorative occasions beyond the simple "rock pile and post" wherever they are put.

Out-vac sculpture can be Government or Sponsor-Commissioned or privately financed, even artist-donated. A prime example of an opportunity for privately financed sculptural decoration will be the home-pride and/or image-conscious need felt by some to mark the exterior regolith mound shielding their own home, neighborhood, entire settlement, or their corporate headquarters or other place of business in some distinctive fashion. This can be as simple as raking patterns. Or distinctively colored thin top-layers could be applied (e.g. very dark ilmenite-rich soil, calcium oxide lime, to suggest two cheaper choices). Or the mound slopes could be accented or even fully paved with cut rocks or molded cast-basalt tiles, even faux "shingles" etc. [See MMM #55 MAY '92, p.7 "MoonRoofs".] Luxuries like this will obviously be more common in close proximity to surface roads from which they can be appreciatively noticed. This would fit the sad but common dishonesty on Earth where only traffic facing façades are given special attention.

Out-vac sculpture of all these sorts, and of kinds we have not imagined, will allow frontier pioneer artists to put a human touch on the lunar surface in the areas where human presence has been or is being securely established. These artifacts will proudly proclaim a clear message:

"This magnificent desolation is ours. It is home."

The role of lunar-derived artforms and crafts in making settlers feel at home will be major.

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MMM #115 - May 1998

HIGH NOON

Coping with Dayspan Heat

HIGHNOON: COPING WITH DAYSPAN HEAT By Peter Kokh

FOREWORD

There is much enthusiasm for a north or south polar Moonbase these days. Can't fault that, especially in the light of Lunar Prospector's positive findings at both lunar poles. The thin frost-mix of ice crystals with regolith powder moon dust grains is a real asset for any prospective base.

Yet one of the advantages stressed most by polar base enthusiasts is the relative ease of "thermal control" at the poles in contrast to anywhere else on the Moon where it becomes "impossibly hot" during the lunar dayspan, 14 and 3/4 standard Earth days long. The Apollo landers all touched down by local midmorning and left well before local noon. It gets well over 200°F out there.

We are so endlessly tired of polar base aficionados and others pointing to the stifling dayspan heat. So we can go to the Moon but we can't figure out to handle so simple a problem as **superficial heat?**

Lah dee dah! Give me a break!

· The LEMs stood exposed on the surface, unshaded from the Sun. The astronauts they supported were only there for a few Earth days max.

Once people come for longer stay times and tours of duty of some months or more, it'll be essential to protect them from cosmic rays and solar flares. Covering their habitats and work modules with a blanket of moon dust six feet thick, will offer such protection. (For a lifetime stay

you'd want to double that.)

Frosting on the cake, it happens that six feet down the temperature is constant year-round, some -4°F . The soil is a poor conductor of heat, and the Sun's warmth does not penetrate that far down, not even with a full two weeks plus to do it.— and no clouds!



· **There is no atmosphere on the Moon to hold heat.**

So surface temperatures are entirely superficial. It can't affect suited personnel by convection then, only by radiation, reflection off the surface.

That's why astronaut space suits have reflective outer-surfaces. Anything which baffles that reflection off the nearby surface and rocks is quite effective.

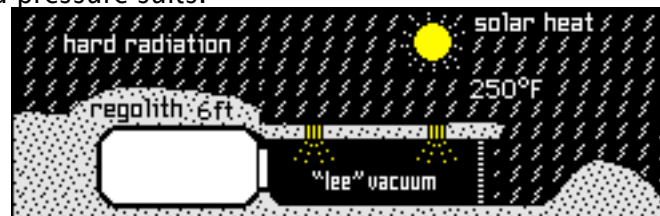
As for direct heating by the Sun itself, people at the poles catching the Sun full on from front, side, or back are far more exposed than those elsewhere who catch the Sun's rays from a higher angle.



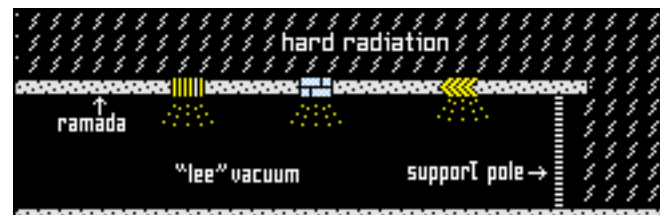
RAMADAS REVISITED — Eight years ago, in the July '90 issue of MMM, pp. 3-4, we ran a piece entitled "Ramadas", illustrated by Dan Moynahan.

We pointed out that a significant fraction of out-vac activities come under the classification of routine chores associated with outpost maintenance and service, change out of volatile supply tanks, external warehouse management, and so on, done in limited definable spaces.

By covering these with sun-shading ramadas or canopies with a minimum blanket of moondust on top, we in effect create radiation-free, UV-free "lee" space in which workers can do their jobs in lighter weight unhardened pressure suits.



But such ramadas can also filter or baffle the direct sunlight. Without air to convect heat, the surface temperature underneath can be whatever we want it to be (amount of modulated sunlight let through). Sunlight can be brought in through glass block, or by bundles of glass fibers, or chevron slat diffusers.



For landscaping aims, these service and warehousing "back yards" can be blocked from passing view by berms, mounds, by walls made of locally produced translucent glass block or sinter block. We need to look at what translucent materials or diffuser designs can be most easily produced from elements we can process on the Moon in near term.

What about various types of milk glass, or even Correlle. Can we locally produce low-E coatings to reflect infrared light back into space, cutting heat transmission? Are there ways to produce both serviceable minimum shielding and moderate diffused translucency for an easy to work under light-but-not-too-bright faux “sky” that would also greatly soften shadows?

And what is the cheapest, easiest way to locally produce the ramada “pan” itself that holds the shielding overburden and the light diffusing elements?

No one else is talking about ramadas and “lee yards”, yet any non-polar lunar outpost without them can be truly functional in its design. These are obvious and essential accessories. If LRS had the seed money to promote a nationwide design contest, high on the list of subject matter would be ramadas. Hopefully, such a design competition is something we will be able to arrange in the near future.

One might expect quite a number of innovative, creative, and resourceful designs, something on which entre-preneurs could then get to work, so that they are “on-the-shelf” and ready for future lunar base operators when the time comes. Moreover, some of these designs may even have profitable terrestrial applications or analogs, the profits from which could finance their development for lunar applications. This is an example of what we’ve been calling “spin-up”.

SUN FENCES & SHADE WALLS — For use at eastern and western exposures (rising early morning sun and setting late afternoon sun) as well as equatorwards at higher latitude locations (midday sun at low sky angles) simple shade walls will provide some relief. These can be made of perforated sinter block or glass block, in both cases letting some moder-ated light pass through – enough to see into the shaded area.



Lightweight unrollable fiberglass tight weave mesh sun-fencing would operate similarly, set up to partially shade areas where suited individuals are going to do geological field work or prospecting.

MOBILE CANOPIES & AWNINGS — Simple protection from direct solar heating is available for travelers and campers as well, just by doing what they would do on Earth. There’s no mystery. Keep in mind that there is no air to hold and transfer heat by convection or conduction on the Moon. So, except through boot soles or tires, heat gain can only occur through infrared radiation.

We must drum into our heads that, however counterintuitively, this hyped up 250°F dayspan heat is only a super-ficial, easily managed effect. Again, because there is no air, and hence no wind, awnings and swiveling sun-tracking mobile solar collector arrays doing double duty as sunshades, can be very light weight, even flimsy.

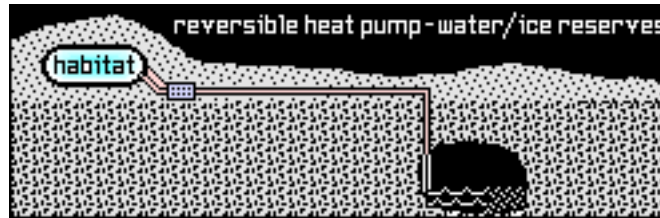


INDIVIDUAL PARASOLS — Even space suited persons out in the field can minimize direct solar heating. While a helmet or headgear attached parasol might be quite impractical on Earth, the lack of air and wind makes even a gossamer helmet shade “no problem”.

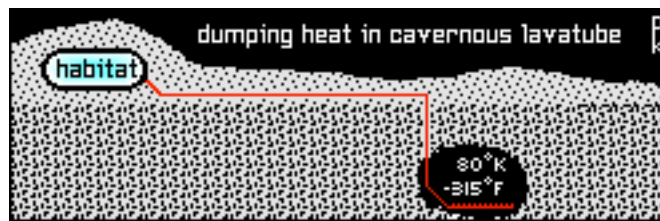


ENHANCED HEAT RADIATORS — Absolutely the most lame claim of the “oh, it’s too hot!” crowd, is that it is difficult or impossible to radiate away excess heat to the black sky when the Sun is up. We are

in the space business. We are alleged to have constructively creative imaginations and a “can do” attitude. The “can’t do it” response isn’t what got us to the Moon in the Apollo days, and as an excuse to divert attention to Mars, where that attitude won’t work either, it is not only dishonest but self-defeating. Enough, a picture is worth a thousand words. Here’s three of them to prime the brain-storming pumps.



The storage area could be any hollowed out volume. A lavatube reservoir would be useful for larger settlements with growth potential. Systems of this sort have worked well in northern U.S. areas over the last two decades, equalizing not just alternating cold and hot fortnights, but much longer winters and summers. We need reserve water. This would be a good use to which to put it when not in use directly.



Typically hundreds of meters in width and height, many kilometers long, cryo-cold lavatube surfaces could suck up a lot of heat. In short we need not cower before lunar dayspan heat.

If we are going to make it into space, it will not be courtesy of those who look at all the obstacles and disadvantages and cry “it is too much, too difficult, and give up. It will be courtesy of those who look at these same challenges and accept them as that, challenges to be overcome by human ingenuity.

“Tell me all the reasons why we can’t. Then tell me how we are going to do it anyway.”
<MMM>

[Time to cool off!]



SKIING ON THE MOON

Inspired by an episode of PBS’ European Journal, 3/8/98 Ch 36 Milwaukee, from Deutsche Woelle TV

HARVESTED ICE RESERVES

Any company in business to market lunar polar ice reserves will need to keep an inventory ahead of reserves if it is to take advantage of market opportunities as they occur. This reserve can be stored in

pressurized volumes as liquid water, or as manageable ice cubes or blocks kept by controlled temperature and humidity from welding into a solid unmanageable block. Another very handy way to pile up such a harvest would be as snow, again at carefully managed temperatures and air moisture.

Now there are times when demand will be brisk, and reserves will run low. Harvesters will be hard put to keep up. At other times, they may get well ahead of the game. Question: how do you make money out of an idle reservoir of harvested ice just sitting there, waiting for a buyer? Why build a ski hill, of course!

In Florida—flat Holland, Dutch entrepreneurs, hoping to tap into a suspected market of would-be Alpine skiers without enough guilders to travel to the Alps, have built a ski hill! The hill is modest, as hills go. But without competition for hundreds of miles around, modest will do. To extend the season, they have covered their ski hill slope in a Quonset shed, the better to maintain just the right conditions. Could not lunar entrepreneurs do the same thing?

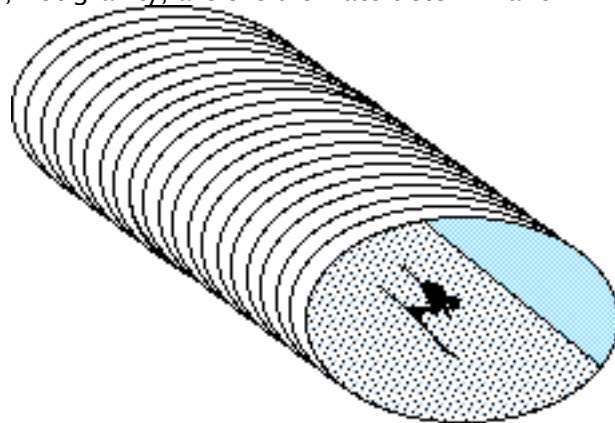
CONSTRUCTING THE HILL



At the lunar poles, one would not have to construct a hill. Hills, in the form of the inner slopes of crater rims, abound. In fact they frame the permashade areas in which the ice reserves are to be found. Right structure, superlative size, right location. A little grading to smooth the beginners run, a little more to make the intermediate and advanced runs more interesting, cover it all with a shed, and Voilà! No, not quite. Pressurize it and the shed would blow off and the air would be gone. The shed has to be an ovoid or cylindrical tube that is pressure tight, bending to fit the graded slope bed prepared for it. Then, and only then, is the air tight cylinder pressurized, and snow piped in and deployed to the right thickness or better.

On the Moon where the lunar gravity is but a sixth that of Earth, even on “fast” snow, it would take time to build up satisfying speed. But even in sixth-weight, considerable speed can be built up – it just takes a longer warm up run. But the slopes of lunar craters can be thousands of feet, 2–3 kilometers long – plenty long enough, given the money, the snow reserves, and the entrepreneurial daring.

A permanently shaded equator-side inner slope of a near polar crater would make temperature control easy. Air pressure need only be high enough to keep the snow from subliming, but no higher, e.g. as high as Everest. And the thinner air would actually mean faster terminal speeds than we achieve on Earth, where air pressure, not gravity, are the ultimate determinant.



The shed roof could be glazed for glimpses of starlight, but given enough artificial interior illumination to see where one was going (unless we use blacklight! – hey!) a faux firmament finish on the ceiling would be fine. Or even a matte sky blue for those who want to pretend they are on Earth. In fact, the setting could be engineered to change seasonally or on some other schedule.

STAFF RECREATION & TOURIST INCOME

Who would ski the Moon? First, the people doing the harvesting and staffing the lunar polar operations – in their free time. It would be an enormous perk. Telecasts to Earth of this activity, or of intramural tournaments would lure tourists for the ultimate ski experience. Skiers are like golfers. No course is the same, and life is never boring as long as there is a run or course they haven’t tried.

Skiing suits and equipment need not be much different, if at all, from what is currently used on Earth. In time, the special nuances of lunar skiing will encourage a unique specialization of wares and wears as we try to push the sport to newer limits.

OUT-VAC SKIING ?



WITHOUT SNOW ?

Skiing on lunar polar indoor craterslope snow runs may be only the beginning. This is one sport which few had suspected might ever have a lunar translation. But there could be other lunar-appropriate idioms in which “to ski” might be rendered. This may be but the beginning.

What about skiing in vacuum, on something other than snow, something slippery and non volatile. Surely I jest! Not that long ago (to an old timer like me) something new under the sun was discovered: “Buckminsterfullerene” a hollow, spherical form of carbon with the formula C_{60} . Yet it was only new to us. Carbon sixty had been there all along, and too boot, in a form we are all familiar with, soot! Could a slope piled with carbon buckyballs be slippery in vacuum? It would take a nifty experiment to determine if the answer is yea or nay.

But if so, where would we get the carbon? Right where we get the water ice. For the lunar polar ice reserves are a gift of the comets, and carbon oxide ices are the second most common volatile in comet cores. Lunar ice should be clathrate, a mixture of water ice and carbon oxide ices.

There are plenty of good crater slopes near the poles and away from them. The northern near-side maria have a number of famous mountain massifs: Mt. Piton, Mt. Pico, Mt. Bradley, to name a few. With bucky-snow in vacuum, the higher temperatures away from the poles would be no problem.

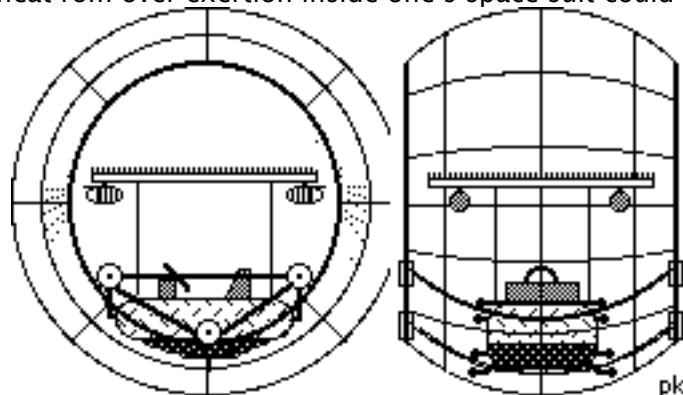
But let our imagination wonder yet further afield. Silicon is said to be an analog of carbon, both having a valence of ± 4 . Could there be a silicon analog? There’s lots of silicon on the Moon. This rock-making element is second in abundance only to oxygen. But there probably is no analog – while the valence is the same, the bonding tendencies of silicon and carbon are quite different. Silicone chemistry does not mirror organic carbon chemistry for that very reason. It’s unlikely that chemical engineers will be able to come up with “silisnow”.

FOR SOME – THE THRILL OF TEASING DEATH

Regardless, skiing in vacuum would create risks and dangers that would attract only the most proficient and daring, those for whom the ultimate high is to risk death and win. In vacuum, over long enough slopes, speed would be limited only by the friction of the skis on the slippery medium, not by wind resistance. And at any speed, let alone very high speeds, a fall accompanied by a suit puncture could lead to speedy death. But if there is a market, ever more rugged and puncture resistant suits and helmets will be developed.

Or, instead of skiing or ski-boarding, devotees of the vacuum slopes could take to sealed and pressurized toboggans engineered to be roll-over safe at very high speeds. Or we could ride weighted cars inside wire or pipe “atlas-spheres” allowed to roll downhill where they will. We talked about a cross-country version of such a vehicle in MMM #81 DEC ‘94 p. 1 “Lunar surrey with the fringe on top”.

Watched “American Gladiators” lately? Seen the “Atlasball” segment? Next time, picture space suited lunar thrill-seekers working their geodesic cages along a rally course of craterlets etc. Might be fun if the sweat and heat rom over exertion inside one’s space suit could be handled!



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

But the idea here is to go “down”, “fast”! Yes, there are the Nordics and the Alpines. To each his/her own. Never tried cross country, so I don’t quite understand the lure.

LUNAR AMUSEMENT PARK RIDES

Then there are roller coasters. Pressurized cars plying an out-vac track that was high enough, could build up speeds never experienced on Earth where air pressure sets up an artificial "terminal speed" that can't be exceeded in an unpowered run. Some of the down hill run of the coaster could be above the lunar terrain, but some of it could be tunneled into the surface, perhaps opening into a lava-tube, with a sphincter gate, resembling so much normal hum drum lunar surface, opening just in time to swallow the horrified passengers into the pitch darkness of the lunar netherworld.

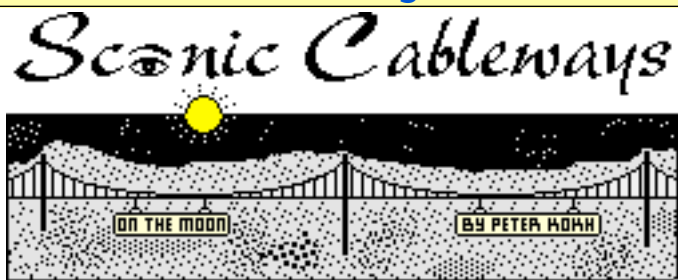
In the sixthweight, with the absence of wind, towers could easily be built miles high. Bungee jumping, anyone? But isn't all this another article?

OUR POINT

Wherever there is significant gravity and a community of people settling-in, sports will rise to the occasion. Ever since we (most of us) were first flung into the air by our fathers as infants, the thrill of a gravity-polarized environment is a lesson that we have never forgotten. Of course, not all things that are possible catch on as lasting fads (e.g. going over Niagara Falls in a barrel!)

Maybe none of this will come to pass. But nothing imagined, nothing attempted. And nothing attempted, nothing achieved. So we take the first step and dare to imagine. Those of you who have never skied, never felt the rush of excitement that it brings, will not understand. Stay home! Those of us who have felt what it is like to challenge the slopes and control our paths will dare to push this sport to its furthest limit, even on the Moon. <MMM>

MMM #117 - August 1998



SCENIC CABLEWAYS By Peter Kokh

On Earth, cable railroads and aerial gondolas have been used to transport people in hilly, mountainous country for two centuries, both for basic transportation, and for bird's eye scenic viewing of spectacular and beautiful terrain. Various forms have been tried with great success from inclined planes, cog-railways, funiculars and aerial systems.

On the Moon, once there is a plurality of globally scattered settlements, and enough traffic, we are likely to see the emergence of some strangely familiar forms of mass transportation. Moon Miners' Review # 13 AUG '93 pp. 10-14, reported the results of a group brainstorming effort on the prospects for "Railroads on the Moon." From time to time we have mentioned in passing some other possibilities. In this article, we take an in depth look at one of them.

In this article, we propose a cable suspended boxed monorail design that would lend itself to long-distance travel over rugged terrain without necessitating extensive road grading, yet allow a heightened appreciation of the scenic moonscapes. The towers needed to suspend the system at regular intervals could be set in place by spider-legged walking vehicles, to minimize disruption of the surface below and keep the setting as pristine as possible.

INTERMARIA PORTAGES & SHORTCUTS

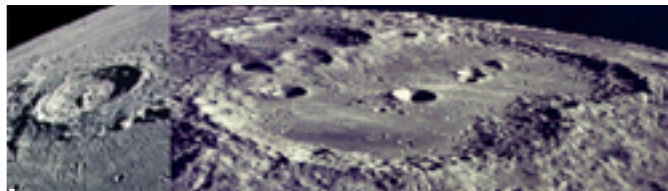
On the nearside of the Moon, perhaps the majority of good settlement and outpost sites are along "shores" or 'coasts" of the interconnected Nearside Chain of Maria. This allows easy "highway travel" in general. However, one of the most-often favored maria for settlement sites, Mare Crisium, the Sea of Clouds (the easiest feature on the Moon for the naked eye to pick out, a real media plus) is land or more accurately highland-locked. Surface travel between the Sea of Crises and the nearby seas of Tranquility (to the west) and Fertility (to the south) would require surveying logical low-grade routes through the crater-pocked highlands.

Even between contiguous maria, there are often sizable “promontories” or “headlands” to detour around. Such detours will add hours to the time needed. And even within a maria, inconveniently placed sinuous rilles (collapsed lava-tubes) will mean either hairpinning routes down one slope and up the other or a detour that could add hundreds of kilometers or miles to the trip, and many hours. Roads and even railroads will eventually find their way up and through and down low grade “valley routes” much as they do on Earth. Such obstacles will yield to them. Meanwhile, such obstacles present opportunities for scenic cableways portaging both passengers and freight – much as do waterborne ferries here on Earth – “to get to the other side” where freewheeling travel is again available.

On the much more rugged lunar Farside and through both polar regions and southern Nearside, cableways may be an early option of choice.

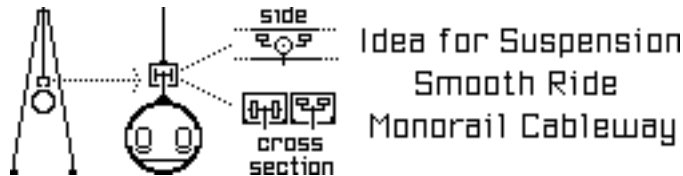
SCENIC RIMWAYS

Just as on Earth, recreational travel on the Moon will not necessarily be to a “destination”. We go on cruises to enjoy and relax, not to go somewhere. We can foresee scenic cableways along the rim ridges of the Lunar Apennines SE of Mare Imbrium, or along the shorecrest of Sinus Iridium in NW Mare Imbrium, or along the coastal ramparts of Mare Crisium, or along the rims of major craters like Copernicus. In fact such excursions, ending up where they started, are often cheaper than round-trip straightline travel to magnet destinations. Of course, such rim and crest following cableways will also work as practical ways to travel between various shoreline settlements.



Copernicus Rim ----- Van de Graaf Rim (Farside)

For tourists from Earth, such cableways will become a favorite, giving them a much better feel for the undisturbed rugged lunar terrain, as well as more sweeping views, than will graded highways with their cuts and fills, tunnels and bridges.



POINTS: Using the suspended monorail box beam, the ride will be much less up and down, smoother, with moderated changes in elevation and grade, allowing faster speeds. The box beam shades the “truck” that rides within it. There are spring loaded wheels that ride the inner sides of the beam and keep the truck centered so that the suspending bar or beam does not touch the sides of the box beam opening. The beam could be made of fiberglass reinforced lunar steam-crete¹ sections that would neither conduct dayspan heat or nightspan cold to the same degree nor expand and contract with dayspan/nightspan temperature changes as much as any beam made of available engineering metals: iron & steel, aluminum, magnesium, or titanium. ¹ T.D. Lin of Construction Technologies Inc., who had first found a way using Apollo return samples to make lunar concrete, has now found a way to make it using the very minimum of water by steaming the mix. <MMM>



Landcruising Gypsy House Boats

By Peter Kokh

LIVING ON THE ROAD LIFESTYLES

What concern NASA has given to provision of **radiation protection** to its people on the Moon has been concentrated on methods of banking regolith soil around fixed habitats and shelters. This writer has never seen a NASA or contractor drawing or illustration of a lunar surface vehicle that

paid any attention to the question. The assumption is that no one would be out on the surface long enough for it to matter, that surface sorties would be as relatively short and limited as the sight lines of those “in position” who talk about lunar bases.

But in any kind of longer term vision of what is likely to happen in lunar development and settlement such an assumption is patently absurd. Even an infant lunar global market is certain to sprout the following (and other) types of vehicles in which drivers and crews will be on board for very extended periods in which, without protection, they would accumulate potential lethal doses of radiation.

- fleet and owner-operated long distance truck rigs
- large gas/ice harvesters always in “the field”
- mobile markets, plying the settlement circuit, picking up special crafts and manufactures of one community to hawk in others at dockside markets [see MMM # 35 MAY '90, pp. 6-7. “Tea & Sugar” on the same lifestyle niche in the asteroid belt]

If lunar development goes anywhere at all, it will rather quickly move past the “tentative” stage in which personnel involved have come for short and temporary tours of duty, to then return to Earth to brag to their grandchildren how they were once on the Moon. If those “in position” dare not allow themselves the luxury of thinking in such “unsupported” terms, we, whose primary concern is to pave the way for just such long-term realizations must tackle the problems that will then arise.

One option, of course, is to limit accumulated exposure by making mobile assignments temporary, not allowing anything like lifetime careers “on the road”. But this is an unnatural choice. While living on the road is a lifestyle that does not appeal more than momentarily to most, it does suit the temperaments of a steady fraction of any population, who find themselves happiest in outdoor mobile occupations. Rather than limiting people, we should seek to turn them loose. People always do their best when they are following their own stars.

In any natural unfettered lunar society, there will be the long distance truck drivers, the traders, the road builders, the field prospectors, the out-vac sportsmen, whose spirits would suffocate within the confines of even the best designed settlement. How do we make a place for them, not just in society, but also out on the road and in the field, a place in which they are moderately safe from dangerous doses of cosmic radiation? [The solar flare question is another matter altogether. See MMM # 37 JUL '90, pp. 4-5, “FLARE SHEDS: Butt-savers in the lunar out-vac”]

TORTOISE SHELLS – THE CARAPACE

What seems to be needed in all the types of vehicles mentioned above, is some sort of overhead and side layer of sufficient thickness to harmlessly absorb incoming radiation. This cannot be conveniently minimized. Too thin a radiation barrier is worse than none at all because of the even more dangerous secondary radiation that occurs when cosmic rays hit layers between about 20 and 200 centimeters (8” and 2 yards). The first thing that comes to mind is to use garden variety regolith, pre-pulverized lunar soil, in bin rows to keep from shifting. Even in light lunar gravity (“sixthweight”), this would entail a loading of 180 lbs per square foot, nearly a ton per square meter. Talk about road-hugging vehicles! Obviously, such vehicles would have high centers of gravity and need to be very wide-tracked to compensate.

Can we find ways to lighten this burden? Like the tortoise and turtle, crews of constant use lunar vehicles will need to take their shelter with them. But doing so with “raw” and otherwise “useless” shielding threatens to bog them down in tonnage.

LIGHTER WEIGHT SHIELDING MATERIALS

There are two reasons to avoid cheap raw regolith for this purpose. It is relatively heavy, 2.8 gm/c³, and loaded with middle weight atoms that increase the amount of secondary radiation. By weight, 76% of regolith is constituted by the lighter elements [with their atomic weights given]:

O oxygen [16] Ma magnesium [24]

Al aluminum [27] Si silicon [28]

Another 22% of regolith (abundance averages for highland and mare soil) consists of:

Ca calcium [40] Ti titanium [48]

Fe iron [56]

Highland soil has more light magnesium and aluminum but also more heavy calcium. Mare soil has more titanium and iron. In advance of the capacity to remove Ca, Fe, and Ti altogether, highland soil, free iron fines removed by a magnet, would be the better choice. This may be the practice for some time, and it will be quite feasible if early settlements are established, as we've recommended, along the shores of the various maria or lunar lava plains, i.e. in coastal mare/highland zones where access to both the most common types of lunar soil are readily available.

Once we can do extensive processing, the following options suggest themselves either singly or in any available easy to produce mixture [molecular weights, followed by **average atomic weights** given]:

Silica SiO2 = 60/20	Magnesia MgO = 40/20
Alumina Al2O3 = 102/20.4	Magnesium 24
Aluminum 27/27	

Foamed silica glass or hollow quartz Spherules would seem to be the most attractive possibilities, if they can be manufactured as a cheap byproduct of other priority materials. As quartz (pure silica glass) is transparent to solar ultraviolet, it is likely to be a high priority product of early lunar industrialization, as waste water could be purified of bacteria and pathogens quite simply by exposure to the sun in pressurized quartz-paned tanks. But silica, magnesia, and alumina are also likely to be produced early on for various uses. And aluminum metal alloy could conceivably be foamed.

In similar situations on Mars, where both hydrogen and carbon are much more abundant, such passive shielding materials as C graphite [12] and simple solid or baffled liquid hydrocarbons [average atomic weights c. 4-5] would offer superior choices. On the Moon, even given the lunar polar hoards of cometary ices, such use of these elements would seem profligate [unless liquid propane becomes the fuel of choice instead of methane, in which case overhead and/or side-mounted fuel tanks could do double duty].

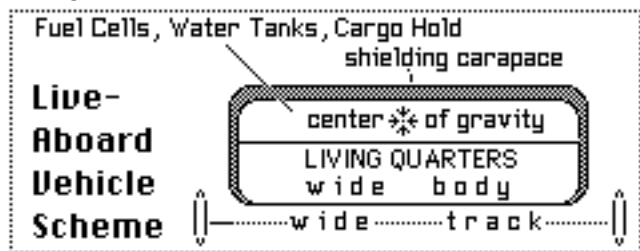
SHIELDS OF CARGO, FUEL, SUPPLIES, BATTERIES

Above we called regolith and regolith derived shielding "otherwise useless". Worse than useless, it will make for slower acceleration and braking. What about dual use materials and objects: items likely to be part of, or carried aboard which, if placed above and/or to the sides could do double duty as shielding, thus keeping total loaded weight (and fuel consumption) of the vehicle down? This is an area already much investigated in the design of deep space craft for human crews who need radiation protection but can ill afford the exorbitant fuel penalties of extra mass\taken along for shielding purposes only.

Among such items are: banks of fuel cells, the bottled cryogenic hydrogen and oxygen that feed them and the tanks of water that they produce, other water reserves and water in treatment, and cargo holds

With proper vehicle layout and design, such double duty shielding may be able to handle a large portion of the load, using the inert regolith-derived (atmosphere-derived in the case of Mars) materials for filling in and topping off. If cargo holds were counted on as part of the mix, vehicles would have to fill them with inert dunnage when no cargo was available for return trips.

But that very prospect may make some otherwise marginal products marketable as their shipping costs could largely be waived. For this purpose a market should arise for standard stackable containers; standard construction bricks could serve as salable dunnage in a pinch. Other creative and enterprising solutions will arise. **MMM**



Among such items are: banks of fuel cells, the bottled cryogenic hydrogen and oxygen that feed them, and the tanks of water that they produce, other water reserves and water in treatment, and cargo holds






Cruising Mare Crisium



Cruise “Ships” on the Moon’s Lavasheet “Seas”


By Peter Kokh

 **What is the essence of a cruise ship?** May I suggest, dictionaries aside, this working definition: an internally spacious and many-activity supporting means of transport that goes nowhere in particular over a non-distracting surface so that its passengers have nothing to do but relax, relax, relax.


The sea is essential only as a metaphor for a non-distracting motionscape. This can be a terrestrial ocean or sea*, the surface of relatively featureless lunar or Martian lava plains, and above all empty stretches of interplanetary space itself.

*There are places on Lakes Superior and Michigan and Huron, the Aral Sea and Africa’s Lake Victoria, where ships lose sight of land for appreciable stretches.

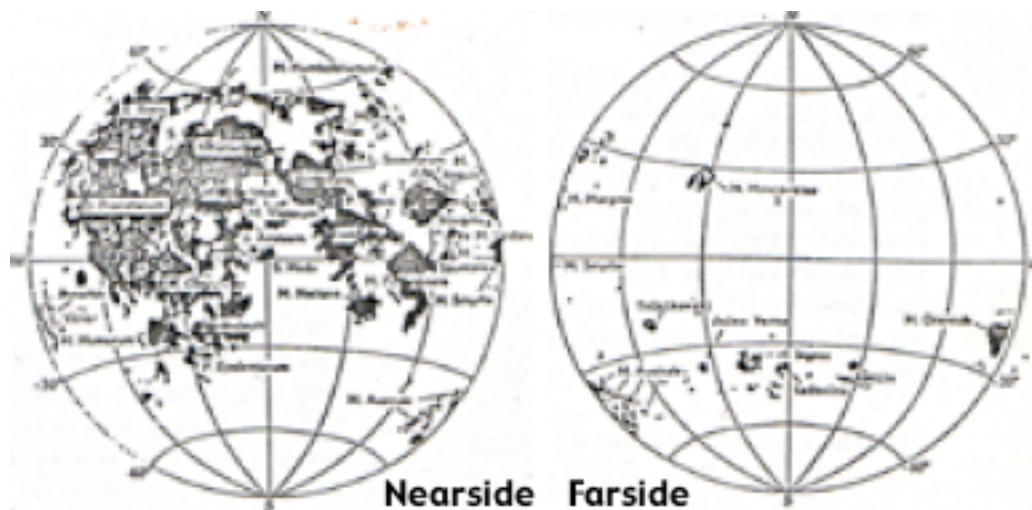
Such plainscapes, watery or dusty, support vessels or craft that can be gargantuan in their dimensions. Bodies of water call for streamlined hulls because the craft in question must “part the waves” to make progress. But by using a double hull catamaran plan, ocean ships can be amazingly wide. Port congestion with close-spaced piers may introduce an artificial constriction not “of the essence”.

 **Why cruise “ships” on the Moon?** Because they will provide the same welcome relaxation and escape from routine as do their terrestrial counterparts. As here, the object will not be to go anywhere, even for an extended visit (e.g. Europe), though brief visits may be made to small ports with local color to spice up the vacation: San Juan, Nassau, Ochos Rio, Aldrin Vale, Alpine Valley Junction, Rover Crossing.

As with terrestrial “floating resort hotels”, over time a symbiotic relationship will develop between the ships and their ports of call. The quest of the passengers for variety will work to motivate local artists, craftsmen, and performers to produce unique items that give their “port” a special and hopefully memorable flavor. Produce or get dropped from the circuit. This motivation with both public and private support will be strong, even if service to the tourist trade is a secondary part of the local economy. Occasionally the “ships” will test visit new stops, on or off their accustomed circuit(s).

 **Where on the Moon?** Many locations on the Moon are suitable for this kind of vacationing. Keep in mind that rilles are as much an obstacle, however, as craters of size. Treat them as barrier reefs and large islands respectively. Even so, most of the lunar maria have sizable continuous stretches that should be negotiable by large, seemingly “floating” structures. In each mare, proposed routes will have to be surveyed carefully for obstacles and alternates. The whole idea is not to have to “fix” the route by cutting or filling or bridging.

Nearside “Seas” – Farside “Seas”



On the Nearside, since most of the large maria are interconnected in one great “Chain of Seas”, large scale cruising is a likely development. There is even one natural ready-made intermare canal, the Alpine Valley, that connects NE Mare Imbrium with S Mare Frigoris east of the conspicuous crater Plato.

While scenic shore-lines and other natural features will give some potential routes a big boost, in the end it will take the efforts and energies and imaginations of individuals to make it real. And that is something that can never be taken for granted.

Cruises on any of the maria along the limb (N-S East Limb: M. Humboltianum, M. Marginis, M. Smythii, M. Australe; West Limb: M. Orientale. L. Veris) where the Earth appears to rise and set in the sky monthly due to an orbital eccentricity effect known as “libration”, could be popular. During stretches when the Earth is just below the horizon, especially during local nightspan, the Milky Way will dominate the skies in a way that no human has yet experienced.

Nightspan cruising will be more popular on Farside (M. Muscoviense, M. Ingenii, Tsiolkovsky, etc.) if powerful blacklight headlights in the absence of both sunlight and earthlight does indeed show the moonscapes in a magical guise. Experiments on Earth with Apollo Moon samples in a dark room should tell us whether that is something to pursue or not.

⚓ The idea, we said, is not to have to “fix” a route by one kind of civil engineering or another. That said, there is precedent for just that on Earth where channels have been dredged, rivers dammed, canals dug or blasted, and locks installed to allow navigation where it could not otherwise have been supported. Cheating? To purists perhaps, but few practical people would give it a second thought. Pragmatic acceptance of “helpful” engineering will be accepted on the Moon as it is here. In each case, the engineering feat will quickly fades into the background or asserts itself to provide special, even featured interest and enjoyment.


Overland cruising might even be supported along very carefully chosen highland routes through chained stretches of so-called “intercrater plains”. These favorable locations will be few and far between in the lunar highlands covering 70% of the surface. The corollary is that where they do exist in extent large enough to support such activity, this will be an economic incentive toward establishment of outposts in the area. In most cases this will be but one “plus” to be combined with other advantages outweighing any disadvantages before development will happen. Just one town at the “head” (i.e. nearest to a beaten path or inter-settlement highway) of such a proposed circuit of smooth-going terrain may be enough to get the ball rolling, cruise excursions giving rise to other stops along the route – eventually.

We do not suggest that cruise activity be an important factor in the establishment of early era secondary settlements, for one simple reason. A Cruise industry presupposes a large established population in which at least some hundreds of people may be motivated to take the same kind of vacation at the same time. That won’t happen anytime soon.

Obviously, however, the way to start is small, e.g. with mare “yachts” and “schooners” that handle a few dozen to a hundred paying passengers plus crew. Indeed, mare cruising is likely to start with an upgrade of a live-aboard lunar “houseboat” of the type described in the last article. Design solutions must progress as well from smaller craft to larger ones. Of course, not everything can be scaled up or down. There are size thresholds above which things become possible for the first time and at which old

tried solutions are no longer suitable. But one must never set the working threshold too high, lest one put it out of reach!

So in this article we are leapfrogging past the first decades of the frontier. But again our purpose is the same, to show that a surprising variety of activities we accept as commonplace on Earth (e.g. excursion cruises!) can be supported in some analogous way on the Moon. We want to expand the envelope of imagination and expectation which, if it were to rely only on the vision of NASA-contractor horse-blinder minimalism is pretty skimpy. It need not be.


 **We confine our scope to “defining” the functions of our topic – a lunar analog cruise ship resort hotel.** Once again we invite the reader to provide constructive criticism as well as to suggest design architecture, engineering, mechanical, power plant and fuel options that work with the basic concept to promote its eventual salinization. To contribute your ideas, concepts, problem identifications, etc. either by email or stamp mail, see the contact information on page 7, column 2 “Reader Design Input Welcome”.

 **Here are some interior design considerations:**

- ◇ size and passenger capacity (50–2000?)
- ◇ adequate shielding carapace over top and sides
- ◇ side holds for supplies and equipment lockers
- ◇ adequate solar flare storm shelter as parking under a standard flare shed is out of the question
- ◇ substantial mini-biosphere and life support with allowable passenger tasks and involvement
- ◇ resort hotel accommodations and features
- ◇ solar atrium – thick layers of glass composites or honeycomb of bundled fiber optics cells
- ◇ decktop observatory
- ◇ mall offerings and features
- ◇ diversions and entertainment
- ◇ crew promoted networking and socializing
- ◇ other onboard services
- ◇ full spectrum communications and libraries
- ◇ luxury touches
- ◇ carry-aboard coaches to take passengers to nearby scenic overlooks etc. over terrain the cruise-ship cannot negotiate – these can double as “lifeboats”

 **Here are some mechanical considerations:**

- ◇ oochie and nuclear power alternatives
- ◇ desired speed cruise 20 knots , flank 40
- ◇ use of “harbor tugs” for precision berthing
- ◇ very wide track to compensate for high center of gravity in a low gravity environment
- ◇ suspensions, track width, wheel radius, and clearance chosen for maximum stability, low sway ignoring small craterlets and boulders
- ◇ possible lowerable surface skimming observation platform for soft-suit moonscape observation in smooth terrain
- ◇ possible use of drag rakes to minimize wheel wakes in the dust, keeping the “sea” trackless

 **Here are some legal issues:**

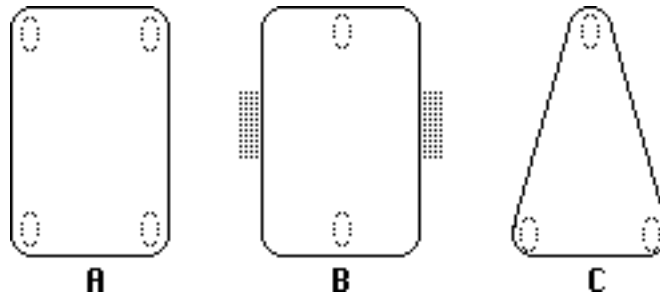
- ◇ Establishing cruise preserves to make as much as possible of the circuit corridor within flanking horizons (from the highest onboard perches) off limits to other surface vehicles to help preserve the trackless character of “open sea” (in concert with the drag rake feature mentioned above).
- ◇ Restriction of transecting corridors open to other surface vehicles in the vicinity of crossings with tunnel underpasses where possible
- ◇ Possible exemption from local government restrictions on gaming and gambling
- ◇ Traditional power of “ship” captains to conduct marriage legal ceremonies



If ever the era of low-paced living and leisurely travel “to” destinations returns, **Ships that go somewhere and take people somewhere** as once great liners took people between New York and Le Havre or Southampton across the Atlantic, land-sailing liners may someday take people “some-where” on the Moon. We do not foresee that. For now we are talking simply of “cruises to nowhere” in which the ship itself is the destination, a vacation site at which you can’t get into your car and hustle around just like you do at home during the work year. Cruising is meant to give a complete break to the pace of life. In this sense, “Love Boats” on the Moon are plausible.



A trio of sketches to prime your imagination. Feel free to start fresh and to look at other concepts.



Some Possible Chassis Plans for a Mare Cruise Ship

A Rectangular 4- wheeled design B Rectangular whimsical “paddlewheel” design C Delta 3- wheeled design

The paddle wheel design (at least the wheel place-ment) would allow greater maneuver-ability (“turning on a dime”) than a conventional 4-corners wheel arrangement. If you wanted to press the paddle wheel analogy and allusion, you could design it so that it would pick up regolith that would fall off the trailing edge like water. Romance should not be pursued at the expense of practicality, however.

A three wheel design might be the most stable, especially over moderately rolling terrain (“high seas”, if you will) although a conventional 4-wheeler would be fine in really flat areas. Of course, each wheel should be large enough to ignore pockmark craters, and have enough play in its independ-ent suspension to handle those several yards (meters) wide without forcing a detour. A companion ad-vantage of a delta design is that it would allow more passengers to have forward facing lounge seats.



We’ve tried our crude hand at **some elaborative design options that seem promising.** But we’d like to see what our readers can come up with first before publishing any of these suggestions. While this brainstorming is perhaps a century ahead of its time, it is a horizon-stretching activity. More to the point, it is a mind-stretching exercise that will help in imagineering the near term lunar frontier as well.

So jot ideas down as they come to you, let them simmer, and once you sense you have the start of a “critical mass”, start putting them together and see what you come up with, keeping score of problems solved, problems remaining, and problems created. Take breaks as needed, and send MMM the results when you have taken them as far as you can.

If your brainstorming stalls, you might want to look at a CCC design study for an 80 pas-senger Earth-Moon Hotel Cruise Ship [Moon Miners’ REVIEW # 12, January 1993, pp. 2-8.----
<http://www.lunar-reclamation.org/papers/transitel.htm>]. While this study is for a vessel that plies space, not the lunar surface, the features included in the hotel portion are things you might want to take into account in your own design. Some of the design solutions may find a parallel in a mare cruiser, others not. But features included are a minimum:

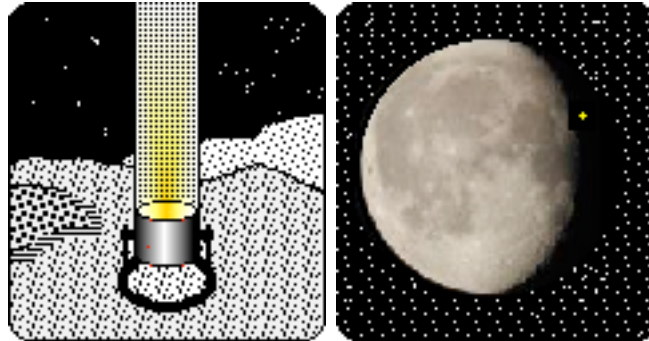
- lobby
- grand staircase and/or atrium
- purser’s office
- gift shop
- hair salon
- dinning room(s) and snack counters
- bar
- lecture rooms
- performance theater/stage
- cinema
- communications/computer room
- gym/exercise room
- library/quiet room
- chapel/meditation room
- dance floor/lounge
- hot tub/massage room
- observation areas
- three or more classes/sizes of staterooms

Some of these functions can be adequately combined in dual purpose rooms. You get the idea.

MMM

Lighthouses & Beacons

on the Moon and elsewhere in Space



LIGHT HOUSES & BEACONS

By Peter Kokh

They can still be found here and there on Earth, old lighthouses, each distinctive, providing ships with navigational points of reference night and day, guarding harbor entrances and dangerous headlands along ocean and Great Lakes coastal regions. Fewer and fewer are in use these days, as reliance on GPS global positioning system units, becomes ever more widespread and reliable for all aspects of maritime navigation. But lighthouses, each distinctive in their design, majestic and symbolic on their headlands or harbor jetties, have a romance and symbolism that persists and grabs at the onlooker.

ASTEROID BEACONS & LIGHTHOUSES

In space, potentially troublesome pieces of solar flotsam, meandering astrobits, might be tagged with transponders, triggered by proximity sensors or upon being scanned (not gawking all the time when no traffic is around). Radio signals could be modulated to yield the identity of the body in barcode or some analogous fashion. If laser pulses are used, they might be in a color that stands out more easily from the starfield, like the red of the ruby laser.

One question is where to put them on a rotating body? Keep in mind, some of these astrochunks rotate or wobble on more than one axis! Convention might decree tagging the north pole of a body (the pole from which left gives the direction of rotation i.e. east). But that pole may be turned away from an approaching ship. An “equatorial” site, any one would do, would guarantee the signal would face anyone nearby at least half the time – these small bodies usually have short rotation periods of a few hours and one would be approaching them for days. To guarantee visibility/audibility at all times, more than one beacon would have to be used. This is a subject that deserves some discussion with the aim of coming up with the easiest, cheapest, most practical “tagging” method, and a solar-charged beacon that can be triggered when needed only. A few bodies might deserve permanent “always on” beacons.

BEACONS & LIGHTHOUSES ON THE MOON & MARS

The surfaces of the Moon and Mars are very well known and detailed photographic atlases for both exist. No problem, it would seem. But remember that for nighttime approaches, these would be of little help. If there is going to be any steady and regular traffic to either body, Lunar and Martian Global Positioning Satellite networks would be a good idea. But why not a lighthouse or visual beacon to mark spaceport locations? Until the clusters of city lights that stud Earth’s planetary nightscapes have their counterpart on the Moon and Mars, such marker beacons would stand out quite clearly, and helpfully.

Sooner than some would think, on both worlds there will be a number of towns and outposts – not just one – and so there will be nighttime surface traffic. Rural areas in between will be extremely deserted, not like our own highways dotted with farm houses and gas stations and country stores and electrically lit billboards! We may see solar-charged mileage markers and junction signs. But why not a lighthouse on some elevated point along the approach to a Major (relatively speaking) settlement? Why not atop solitary mountain peaks or mountain crests when such spots are visible for many miles from all directions? Why not marking “straights” connecting the various lunar seas or maria, or the high flanks of passes through the highlands?

THE LUNAR OVERTURE LIGHTHOUSE PROJECT

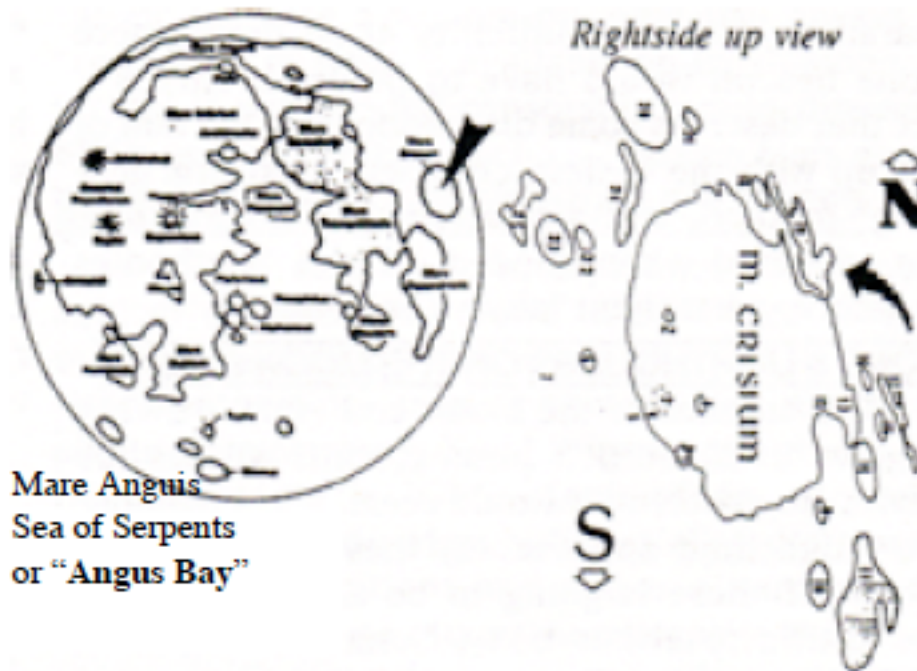
The role of the very first lighthouse on the Moon could be paramount. If it were established before humans returned to the Moon, on the fringe of the intended first Moonbase site, and easily visible to the naked eye of millions on Earth, such a beacon would raise the “consciousness-level” about the pending integration of the Moon into the greater human world, like nothing else could. Hopefully it would increase expectation and garner political as well as monetary support.

Let’s say the Artemis Moonbase Project is finally about to in get off the drawing boards of dreamers. (That Congress would do a major policy turnaround and embrace a lunar beachhead initiative is the more science-fiction of the two possibilities.)

The Artemis folk are looking to the Mare Anguis site as a place to establish their first commercial Moon-base. (Mare Anguis is a small irregular shaped lunar maria off the NW coast of Mare Crisium, the Sea of Crises, and connected to it by an inlet – Artemis would rename the area “Angus Bay” to avoid the direct translation from the Latin, “Sea of Snakes” or “Serpents”.) A Lighthouse/Beacon at the entrance to Angus Bay off the Sea of Crises would be a publicity bonanza, stirring up anticipation and dollars in support of the bold project.

On page twelve, we play the gadfly and try to get such a project started. Brainstorming is fun, and cheap, and of the essence if anything is to become a reality. Those interested are welcome to participate with ideas and identification of challenges. <MMM>

The Angus Bay Lighthouse: Steps in Making it a Reality



By Peter Kokh

See the article “Lighthouses & Beacons” on page 11 of this issue. Putting such a Beacon on or near the proposed Artemis Moonbase site would be unbeatable publicity, make people aware that human return to the Moon is immanent, stir up the enthusiasm that will bring in money, resources, members, and talent, and create the ideal climate for Artemis Moonbase the Movie to be the box office success we need it to be. Here are some of the steps that will be needed to get such a project off the ground.

- ◇ An attitude that we can do it
- ◇ An email list-serve for those contributing ideas to the brainstorming of the project [ABLP]
- ◇ A web address where we can keep track of the Angus Bay Lighthouse Project as it takes shape.
- ◇ Determine how many lumens are needed (and the best color) to make the Beacon clearly visible to the naked eye on Earth during local lunar night, as well as during total lunar eclipses.

- ◇ How close can we come to that candlepower with off-the-shelf commercially available equipment with minimum weight and low cost?
- ◇ Capacity to televise beacon installation in color
- ◇ Capacity to photograph moonscapes and take temperatures during eclipses for science.
- ◇ What else do we need that is off-the shelf?
- ◇ What is available as “military surplus”?
- ◇ Design a solar-power charging system for ABL
- ◇ What else needs to be designed, fabricated etc. from scratch?
- ◇ How much can we get donated “in-kind”?
- ◇ Possible piggyback moneymakers, their cost and weight penalties
- ◇ Vanity electronic bulletin board on the Moon
- ◇ Vanity phone relay
- ◇ Morse code beacon advertising/messages
- ◇ Various entertainment products
- ◇ Beacon base to house memorial ashes
- ◇ Beacon base to preserve signatures of donors
- ◇ Find cheapest way LEO to Angus Bay touchdown
- ◇ Look for possible piggyback ride to LEO
- ◇ Project Manager, local subassembly assistants
- ◇ Inauguration during a lunar eclipse visible from most of North America for maximum publicity

IF our collective brainstorming turns up no show-stoppers (other than money), then we propose this as a project by the Society. True, ASI does not have the funds for such a project, but just undertaking it will flush money out of the woodwork and out from under the mattresses. Diffidence squeaks, enthusiasm rolls in dough. Positive thinking can, negative thinking can't. Attitude is the most priceless commodity in the universe.

- Send early feedback to KokhMMM@aol.com



MMM #120 – November 1998

In Focus: Essence of the Frontier: “Readiness to Reinvent Everything”

Commentary by Peter Kokh

Throughout human history, whenever groups of people endeavored to pioneer new territory, unoccupied or not, they have had to adjust to different conditions than those they were familiar with in their traditional homeland. When there was a choice of prospective new territories, they would, of course, naturally select those that seemed most similar to the one left behind, at least in those respects that mattered most. Steppe peoples favored other steps. River delta people, other river deltas. They would have to make some adjustments, but hopefully not wholesale ones. But nowhere could they expect to find a new home just like the old one in every way. Whether the stress was on finding a new life setting, or on getting out of the old one, except in the case of unwilling refugees, the movers were a group self-selected according to their willingness to start over, their acceptance of the need to “reinvent” many of the givens of daily life to fit the character and available assets of the new home.

Mineral resources, wildlife, vegetation, and climate all affect what the pioneers can make and the methods they might use. On hand manufacturing and craft stuffs will affect home and building styles and construction methods, furnishings, clothing. Sports, games and amusements, even cuisine, will show major or minor adjustment to the new realities.

Those who liked their lives as they were and were willing to change little, stayed behind. Those who left would naturally change as little as possible, but were willing to change and adapt and make do whenever, wherever necessary.

As we move into space locations, we are very unlikely to find any places reminiscent of Earth except in trivial ways (the Arizonesque scenery and similar day/night cycle of Mars). Those not ready to

make major and wholesale adaptations will chicken out once they take off their rose-colored glasses. Sure, we've all seen the very Earthlike concave landscapes painted by artist dreamers trying to sell the L5 vision. But if ever such places are built, it may be long after the youngest of us is dead that the extremely high economic thresholds involved are reached. Nearer term, whether on or under the lunar or Martian surface, or in the primitive shielded construction shack space settlements that we might be able to build in coming generations, the frontier's most Earthlike aspect will be ourselves, the plants and animals we bring along, and our characteristic "we can do it" attitude.

Those who find they have to leave behind too many "favorite things" and lack confidence that they can find/make satisfying substitute "favorite things" will choose to remain behind. Never has there been a frontier, or set of them, so challenging, so demanding of our readiness to reinvent everything. It is a task that daunts us, whether we'd go to the Moon, to Mars, to the asteroids, or pioneer the first crude space settlements. There will be a premium on adaptability and attitude. The tasks involved should frighten anyone taking a real look.

Yet there are ways to adapt, to do without, to make happy substitutions. There are ways to hone the rough edges off the early frontier. Taking a look at them, one by one, is just what MMM is all about. That is what the third "M" is all about. A brash, brazen **MANIFESTO** that shouts: "look, we can do it, and these are some of the things we might try to make ourselves 'at home' in our new setting."

If we remain displaced Earthers, we will have failed. We will need to redefine ourselves as fully settled-in Lunans, Martians, L5ers, asteroid 'Belters' and so on. We can only do this if we leave Earth behind in our psychological rear view mirrors, and forge unreserved new attachments to our new homes. We need a no-holds-barred readiness to reinvent everything. Sure, some material, cultural, and social aspects of our lives will translate readily enough. But others will require major changes, reinvention, replacement, or sublimation.

If the Frontier is a place where we are forced to start anew, it is also a place where we will have a chance to get in on the ground floor, a greater chance to play a significant life role, where we can leave behind the baggage of examples, customs, habits, and strictures accumulated on Earth. The space frontier will be a rugged place where the status quo, the way we do things, is not a given, but something to be created afresh with our input. And all this is a plus. It is this gain in the potential value and significance of our individual struggles that will make all the sacrifices worth while. It is this promise, the chance to start over when the old life has been found wanting or become unbearable, that has been the beacon, the siren, the beatific vision pulling many a person and family to pioneer in the past.

The deep logistical mutual quarantine of the various space frontier sites will offer unparalleled opportunity for social, political, cultural and religious experimentation without attrition to, and erosion by, a dominant and overwhelming mainstream culture. It is not only political, cultural and economic anarchists and utopians that will be drawn outwards, but many individuals with more concrete, more personal problems with their current life situations. The frontier will be an unparalleled scene of renaissance, creativity, fulfillment. **PK**

MMM #121 - December 1998



THE INTERCHUTE By Peter Kokh

Here on Earth, it would be hard to imagine what modern civilization would be like, if for some reason, there

were no aviation, no airplanes, no travel swiftly than high speed rail. Those who romanticize about future settlement civilization on Mars have been greatly encouraged by the fact that Mars thin air could support aviation. Takeoff/landing speeds would have to be very very high, and some lift assist, perhaps in the form of thick, hydrogen filled wings, might be necessary. Yet if it can become a practical reality, that is an enormous plus for opening a world as vast as all of Earth's continents gathered together. The alternative is either substantial investment in a global ground infrastructure – roads and rail, “R&R” – or a resort to suborbital flights.

Such an alternative – to aviation – is taken for granted by those brainstorming human futures on the airless Moon, the impossible ground-skimming lunar bus of “2001: A Space Odyssey” notwithstanding. We will build limited networks of roads on the Moon, we may have high speed Maglev lines in heavily traveled corridors, and overhead cable car lines elsewhere. Yet eventually, even through the high lunar vacuum, when and where intersite passenger traffic demand rises high enough, there may be an “aerial” option. If this idea proves practical it will be because the Moon lacks an effective atmosphere, turning a “liability” into an asset, in true pioneering fashion.

More than twenty years after most of us heard of mass drivers and electromagnetic catapults, we are used to the idea of mass drivers as devices that hurtle small pellets of materials into space at bone- and tissue-crushing accelerations. But a number of people have already expanded their vision to include larger diameter, much longer electromagnetic catapults that could hurl passenger cabins into space at accelerations the ordinary person might tolerate.

It will take more power to hurtle the larger payloads, but less per drive cell unit owing to the greatly reduced acceleration. The total energy needed per kilogram or ton(ne) will be similar. The rest will all depend on the total traffic tonnage in either case.

Writing in the Artemis Data Book*, Greg R. Bennett explains: “A man-rated mass driver would be longer, but not significantly more complex. One limited to 3 g's acceleration, designed to escape** from the Earth-Moon system starting at the surface of the Moon would be 63 miles (101 km) long.”

*<http://www.asi.org/adb/02/10/mass-driver-intro.html>

** assuming a total delta V of 8,016 ft/sec (2,443 m/sec), lunar escape velocity from the surface (7,776 ft/sec) plus additional escape velocity (240 ft/sec) to escape Earth's gravity at distance of the Moon. Formula for the length of the mass driver $S = V^2 / (2 * a)$

An Interchute driver/catcher need not be quite so long; we do not want full orbital velocity, much less escape velocity. But at both ends, it would still be a major piece of infrastructure.

A Caveat here: 3-Gs is quite tolerable for most Earthlings, but it would be 18 times the gravity level to which future Lunans may have become physiologically attuned. Somewhere a tradeoff will have to be made between affordable length of the Interchute installation and the percentage of Lunans who can tolerate a ride. Nonetheless, the idea is an engineering practicality, and this article is based on that.

This transport system demands an extremely high level of precision accuracy, within a centimeter perhaps, after a volley of hundreds, even thousands of kilometers. Anything short (long, off to the right or left) would mean certain vaporizing death on impact at c. 1.5 km/sec. Such precision could never be attained even once, let alone routinely, through an atmosphere of varying pressure and moving fronts. Mars could not support such a system even between its loftiest volcano tops where the air is thinnest.

For such a system to work, there needs to be at least one pair of settlements far enough apart to raise the demand for faster travel between them and with enough potential traffic to pay for the expensive installation. Destinations only a few hundred miles apart might be better, and less expensively served by a Maglev rail system. At the far end of the distance range would be destinations antipodal to one another, at the opposite side of the globe, 3392 miles [5459 km] or about 1 hr flight time apart. Examples:

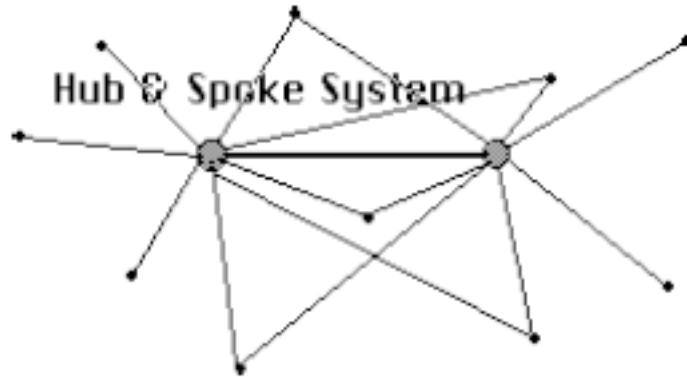
Mare Smythii <=> Mare Orientalis

Mare Imbrium <=> Mare Ingenii

Aristarchus <=> Tsiolkovsky.

GROWING A GLOBAL SYSTEM

The chutes would come in dedicated pairs. One settlement could have several, connecting it with others around the globe.



Given the many-kilometer long length of each chute, a railroad-style “round table” allowing one chute to be alternately aimed at several destinations would be quite impractical. What could be shared between several chutes at an Interchute complex is the charging power source and transit to the host settlement interior.

THE ROMANCE FACTOR

On Earth, most rail systems name their individual regular trains (a few use numbers). Who knows what names would be used on various Interchute lines? Here are some names that seem appropriate to the nature of the beast:

- The Javelin, The Sagittarian, The William Tell, The Arrowsmith, The Bullseye,**
- The Marksman, The Aurora Arrow, The Quivers, Cupid Twins, The Spirit of Port Heinlein,**
- The Spirit of Luna City, The Boomerang, The Retrobullet, Intervolley, etc.**

Alternatives to “Interchute” might be **Flightrail, Skyrail, Sledway, Interballistic, etc.**

The Passenger Coaches

Interchute coaches are not rockets. They are passive bullets or projectiles. The acceleration and deceleration both take place entirely within the “barrels” of a pair of electromagnetic “cannons” “aimed down each other’s throats.” Properly set up, there would be no need for “mid course corrections.” These “coach cans” are passenger conveyances but not vehicles as such apart from the chutes they ply between, as they are totally passive elements.

SHORT FLIGHTS – SPARTAN ACCOMMODATIONS

Interchute travel on the Moon would be very swift, with a maximum of one hour flight times, but in most cases much shorter. As such, accommodations can be rather spartan: no berths, no snacks, maybe even no toilets. All such facilities would be found in the terminal buildings.

LOADING & UNLOADING PASSENGERS

Economics (demand for lowest ticket prices) will demand “maximum packing” of the coach cans. An “aislefree”

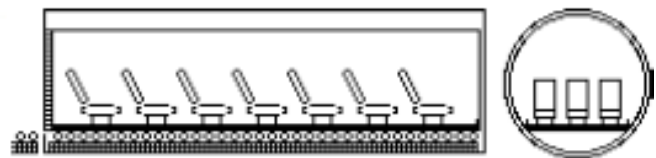
arrangement can be effected by using pre-boarded seating trays that can slide into (and back out of) the Coach Can through an end-installed door-lock.



ABOVE: seats entered from side platforms



ABOVE: seat tray rolling into "coach can"



ABOVE: "coach can" loaded with no wasted aisle space

Approaching the half way point of the zero-g ballistic coast, the coach can will do a computer controlled precision 180° end-for-end flip to prepare for deceleration within the kilometers long barrel of the catching chute ('g's felt against the back of one's seat just as in acceleration in the equally long barrel of the driving chute).



FREIGHT USE IN SLACK TIME?

Could an Interchute system be used to ship containerized freight of comparable mass? Between the same pair of chutes, certainly. Plus passenger runs could be used to deliver priority packages on a ballast-needed opportunity basis. But the chutes themselves could not be re-aimed to other destinations. However, the velocity and length of trajectory can be decreased or increased, by adjusting the electrical power input. This should allow alternative freight distribution terminal chutes conveniently aligned along the same vector or pathway.

COACH CAN TURNAROUND & CHUTE CAPACITY

The reversible trajectory between a pair of chutes is so narrow that cans traveling in opposite directions between the same pair of chutes could not "pass" in mid flight without colliding head on. If only one coach can is used, its turnaround time plus a pair of flight times will yields the capacity of the system per day. The farther apart the two terminals, the less total flights can be made each day by a coach can.

However, even though cans cannot safely pass in the opposite direction, Interchute capacity can be multiplied by following a series of volleys by a fleet of cans all in one direction by a similar series of return flights. Upon reaching its destination, each can would be shunted onto a siding until its position in the return queue came up. The shorter the interval between volleys, the greater the Interchute capacity.

ENGINEERING CONSIDERATIONS

- repeat precision accuracy despite load variation
- tolerable accelerations
- long smoothly graded chute runs
- a suitable pair of sites
- fail-safe power nightspan as well as dayspan
- passengers per megawatt
- maximum runs per day (same coach both ways)
- total capacity versus expected growth of demand

SITE CONSIDERATIONS

The flight path of the chute cans starts off and ends tangential to the lunar surface. All that is needed is enough initial elevation to provide ground and passing vehicle clearance along the exit and entrance glide slopes. Inclination to the level of the surface need be negligible. (In this respect, my title and first page artwork are misleading.) Gentle crater rim slopes are not strictly needed, even if handy. Obviously, it will be harder to find optimum sites in the more rugged highland areas than in the comparatively flat maria or lava plain "seas".

PROFIT CONSIDERATIONS

The first Interchute will be built between the pair of settlements projected to generate the highest traffic demand, combining passengers and priority containerize cargo.

As the system begins to run smoothly and becomes accepted and chute travel becomes routine, the cost of building additional interchute pairs linking one or both of the original pair to other sites will come down. The Interchute might remain a monopoly if the company has the capital to expand routes to include other growing lunar sites. Or it might be duplicated by other companies with the capital. Rival parallel Interchutes between the same towns are possible if demand increases beyond capacity of the original system.

Two towns of a million people a thousand miles apart a hundred years ago might not have had enough traffic between them to justify an Interchute even if it could have been built on Earth. But the amount of economic interdependence and percentage of consumption that rests on trade and traffic has been steadily increasing in our globalizing economy.

On the Moon, once there are two settlements of rival size, interdependent traffic between them will be relatively strong no matter how far apart they are (3,392 miles max, one half lunar circumference.).

And there will be no real alternative, aviation being out of consideration.

NOT FOR EVERYWHERE & NOT SOON

The Interchute is a much more specialized transportation system than are railroads. Nor would realization of this dream be a down payment on "general aviation" in any sort of form realizable on the Moon:

1. Interchute loops, of whatever length and frequency of use, will require a very large capital investment.
2. The further two potential terminals are apart in terms of real alternative road travel time, the greater the time savings and the stronger the incentive to build an Interchute.
3. Towns a few hours apart by good highway would not be good candidates no matter how much mutual traffic that they generated. High speed rail (see MM Review #13, AUG 13, pp. 9-15 "Lunar Railroads") or Maglev would be the choice.

[http://www.moonsociety.org/publications/mmm_papers/rr_moon.htm]

Interchutes will be a travel option on the Moon some generations down the road, when and if the lunar frontier economy fully develops to its full potential, which is considerable. <MMM>

MMM #124 - April 1999



WINDOWS FOCUSED ON EARTH By Peter Kokh

For people living on the Moon, Earth will be by far the most fascinating object in the sky. Technology will let young and old alike scan, zoom, browse, and explore the ever-changing colorful blue marble, for both hobby and education

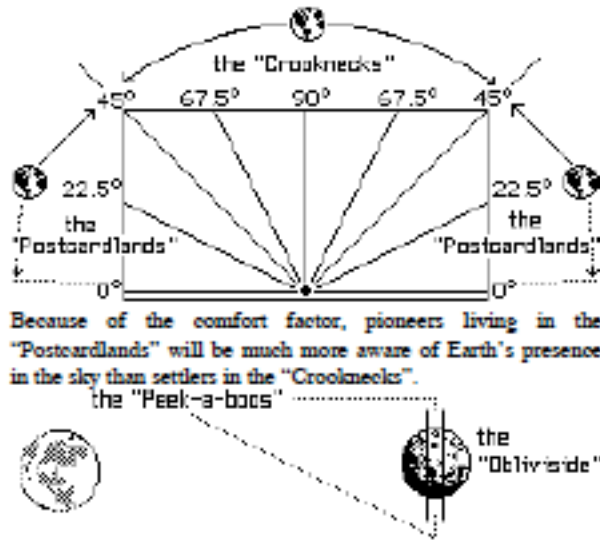
See These Articles from MMM Back Issues:

MMM # 69 OCT '93, pp. 8-9, "7 Wonders of the Moon"

MMM #107 JUL '97, pp 3-5, "Earth: Color Medley Calendar in the Moon's Nearside Sky"

- republished in MMM Classics #10

The Crooknecks, The Postcardlands, The Peek-a-boos, and The Obliviside



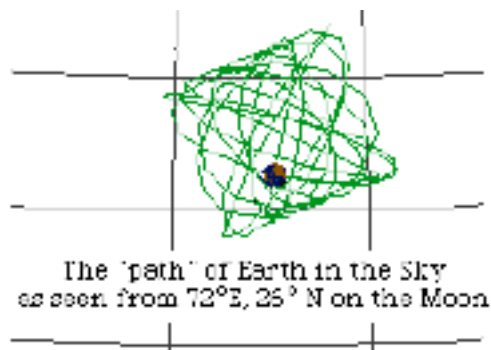
In the central part of the Nearside hemisphere, Earth is either directly overhead or at a very uncomfortably high angle above the horizon. Settlers might aptly nickname these central regions the "Crooknecks." Included is most of Mare Imbrium, Mare Nectaris, Mare Serenitatis, Mare Tranquilitatis, Mare Nectaris, Mare Vaporum, etc.

The "Postcardlands" are nearside peripheral regions in which the Earth hovers perpetually a comfortable 5–45° above the horizon.

Adjacent to these, straddling the "limb" of the lunar globe which forever keeps the same side turned toward Earth are the "Peek-a-boos." Because the Moon's axis is not perpendicular to its orbit around the Earth and because that orbit is somewhat eccentric and the Moon travels faster when nearer Earth and slower when further away, all the while rotating at a fixed rate, about 7° to either side of the 90° East and 90° West lines are alternately turned towards and away from Earth. Together the above three regions cover nearly 60% of the lunar surface.

The remaining 40% is in the "Obliviside," the Farside heartland where Earth is never visible.

From any point on the Moon from which Earth is visible (even part of the time), Earth will seem to drift in the sky, but never more than 7° off some anchor point. Windows designed to focus on Earth will have to take this into account.



<http://www.asi.org/images/asi19700007.gif>

By Gregory R. Bennett. Earth's location above the lunar horizon.

Earth wanders in the sky inside a rectangle approximately 14° on a side, tilted by the observer's latitude. Image generated by Starry Night software on a Power Macintosh 7500/100.

For areas in the "Peek-a-boos" along the limb between Nearside and Farside, sometimes Earth will drift above the horizon, other times, just below it.

Passive Earth-Windows

Given these preliminaries, Settlers having their own homes built, may well choose to include a very special "picture window" with a field of view that always features the beautiful, ever-changing blue

marble of Earth. Such a window might even determine the location of the Hearth, and/or Den/Library/Study, or Family Room in the floor plan.

Such an “Earth-View” window could either show the whole 14° high and wide black, starry domain in the sky in which Earth always appears – somewhere – or, since in contrast to Earth’s brilliance (60–some times as bright as the Full Moon as seen on Earth) all stars in the field of view would be lost in the glare, an automatic shutter could damp out all but say the 3° circle that currently contains the 2° wide Earth. The rest of the field could be some neutral shade chosen for maximum eye-relief.

Even those living toward the center of the Nearside, in the “Crooknecks” where Earth is high in the sky, could enjoy such windows. All it takes is the intervention of a mirror or two at just the right angle for that location, to make Earth appear comfortably just over the horizon. There it would always be, Earth, sometimes crescent, sometimes half, sometimes full. And sometimes, with the Sun lined up behind it, a black hole fringed with a brilliant orange halo – the sunrise – sunset terminator ring, the Sun’s rays catching the dust in the atmosphere at angles parallel to the surface. Full moonlight will dimly illuminate the landscapes, oceans, and cloud decks below.

The day-lit portions of the Earth globe would be a riot of blues, whites, greens, and tans. The areas on after-dusk or predawn sides of the terminator would be ink-black over the oceans and uninhabited areas, and under cloud banks (though some of the incessant lightning dance will be visible here and there in thunderstorms). Elsewhere on the nightside, star-like clusters of city lights would beg for identification, along with forest fires, and the gas burnous from oil fields. (The East Siberian and Persian Gulf areas assault the eye like permanent supernovas.)

Some will never notice, of course, while others will never cease to be in awe – depending on personal temperaments and cultivated interests. As on Earth, those who are “bored” by such spectacle, are inevitably those who are “boring”.

Such passive Earth Windows could be enjoyed without any visual aids, or with binoculars or small telescopes, if the window was designed to be free of glare from ambient sources within the home. Room darkening draperies at the room entrance would do.

Live Electronic Add-on Earth Browsers

One can imagine a variety of after-market electronic aids for Earth watchers. One should be able to purchase and install an electronic Monitor with a feed from a video-cam on the external window frame. Full-color and flat-screened, the monitor could be mounted on the pane surface, in a corner.

Using a hand held remote, one could zoom in on areas of interest, permitting in depth yet still live examination of the spectacle’s features in increasing detail. Or, the monitor could be instructed to ignore all but certain kinds of features, or to fill in with dotted lines coastlines and other features hidden by clouds, or to apply various spectral filters. At a prompt, place names stored in a preprogrammed file, would appear superimposed on the monitor for features on the screen lit by a laser-pointer from the remote. With features like these, young and old alike could learn ever more about Earth in riveting, interactive, live detail.

At first such electronic Earth Window add-on browsers would be found in Corporate offices, then in schools. But eventually, individuals would choose to purchase them for instruction and endless hours of enjoyment at home.

Electronic Whole Globe Browsers

For serious study, schools and dedicated individuals may choose to forgo the Earth Window with its directionally biased live views. Instead they may opt for an all electronic flat wall screen in a projection that shows land masses with minimized distortion. The data on the screen would be live-fed from an array of Earth orbiting satellites. It would be available on the Moon, because it would have been developed for use on Earth itself perhaps in university libraries, planetaria, museums, and other locations, where an initial high cost could be justified. Once available on Earth, a simple relay could make it available on the Moon, even on Mars, to serious and hobby Earth observers at those locations.

Such displays could be made interactive. For example, with a click of the remote, you might be able to blink-switch back and forth between current conditions and say those of the day before, the month before, a season ago, or a year ago – to reveal minor changes that would never leap out on inspection without such a blink-comparator device.

One could impose spectral filters on the display, or entire false-color views revealing vegetation and other thematic “breaks” or discontinuities and contrasts: faults, plate borders, land use borders,

lava fields, drainage watersheds, coast interactive zones; human feedback zones (fertilizer, effluents e.g.); lightning storms, city lights, fire, smoke; chimney contrails; ocean wakes and phosphorescence, etc.

The live feeds would show day and night, of course, but on command, areas currently in darkness could display last available daylight data. Areas in darkness could also be viewed in the infrared. The possibilities that will be possible are endless.

The same screen could show dated information stored on CD-ROM or other media. By the same means, demonstration "tours" of what one can see, study, and learn on the screen could be programmed. Using temporary false color, changes in color intensity or hue, or simply blinking until notice is registered, the monitor could be programmed to call attention, and/or store for later inspection, specific ephemeral events and features and even to search for them from live and stored data scans: incipient tropical depressions, tornadoes, forest fires, oil spills, major mud slides, etc. In this manner, the input from a number of satellites could be collated and monitored by any number of observers around the world, or even beyond it. One should be able to set the monitor in playback mode to show 'movies' in various speeds of fast-motion to show how changes and patterns develop.

A screen within a screen could have a zoom feature to zoom into whatever level of data the available resolution will allow. These Whole World Browsers could take the form of very large wall units, modular screen units, or smaller "den sized" units. For Planetaria, they could conceivably be constructed as giant spherical LED globescreens with walk around spiral ramps.

As to more modest versions, it might take some time before market-demand-triggered mass-production brought them down to family budget size. But the history of market electronics gives plenty of precedent and confidence that just that will happen. A number of rival manufacturers will guarantee that the product is steadily improved and made simpler to use, as well as be more attractively packaged.

On the Moon, such devices might be more popular on the Farside where direct view passive Earth Windows are not an option. Though there might just as likely be a large segment of the population there for whom Earth is all too happily out-of-sight and out-of-mind. The "Obliviside" is a place where people can forget the womb world and turn outward to the universe at large with more single-minded focus.

Interplanetary Globe Browsers

Any planet where large scale visible patterns are changing constantly as Earth or any of the gas giants like Jupiter and Saturn (even the Sun!), or at least steadily, as on Mars, invites the installation of such electronic globe browsing screens and the satellite networks needed to feed them. Jupiter could be monitored from a trio of synchronous satellites – or we could rest satisfied with the quasi-hemisphere visible from a station on Amalthea, inwards of Io. Venus, too, could join the ranks of monitored worlds, once a fleet of aerostat observatory platforms is in place, drifting with the winds just below the Veneran cloud decks. A system installed at and around Saturn's Titan could shed enormous light on that mysterious haze-shrouded moon-planet.

Future Mars frontier settlers could study their own adopted world, or Earth, or even Jupiter's clouds. Time delay will not be a problem as the data flows just one way, and interaction is with the monitor display, not the world being monitored.

The Moon, as dead meteorologically as it is geologically, needs only a screen browser with stored data, no live feeds. Students of the Moon will want an electronically searchable data bank that they can study in any spectrum at any resolution, under all lighting (phase or solar co-longitude) conditions. Once human occupation of the Moon becomes truly global, and the speed of development picks up pace, live feeds may be useful to keep ahead of major environmental changes and their implications.

A trio of close in sun-synchronous satellites in monthlike orbits could continuously monitor the development and evolution of sunspots and solar flares. At less than half Mercury's average distance from the Sun, these "Vulcansats" would have to be hardened. But the Solar Global Browser they fed with data would be one of the most critical factors in allowing human activity in the solar system at large to grow and carry on in relative safety. The satellites and the browsers they feed would automatically compile quick time movies of the Sun's successive twenty-two year sunspot activity cycles.

Around Earth, the needed satellite networks will be built anyway, for, invention of multi-feed monitors or not, scientists do need the data. We could rely on a trio of geosynchronous satellites, say at 80° W (Toronto–Miami–Panama–Quito), 20° E (Warsaw–Capetown), 110° E (Irkutsk–Chunking–Saigon–Perth). Or a series of high inclination Mirtype or Molniya satellite constellations (eccentric orbits with high points at low traverse speed over the target observation areas) could be used, along with some terminator–synchronous low–orbit satellites.

The market for data has been the weather forecasting services, crop surveillance, and other scientific pursuits. But clearly the market for electronic global browsers will be much wider, embracing schools, observatories, museums, space centers, contractor lobbies and conference centers, and even, as we have suggested, in–home dens and family rooms.

Here and Now

As for the Moon and Mars, if the equipment is ready before human presence on those worlds is established, Moon and Mars Global Browsers could be of great use right here on Earth to help settlement candidates become familiar with their new worlds. Certainly they would be popular features at any planetarium or space center, revving up enthusiasm.

Such global browsers would be an invaluable tool for planetary astronomy as well – significant patterns would be noticed on such screens that otherwise might quite easily go undetected. In this case, discovery would become a democratic affair. People everywhere could double check “discoveries”.

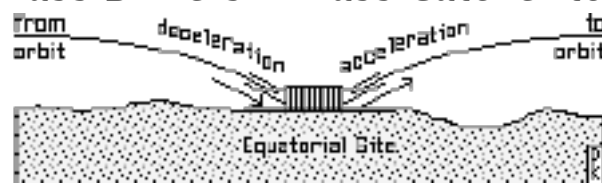
In the process, students will become much more aware of how science works, what it is all about, and that, unlike the case for “faith” and “dogma”, the essence of science is that its discoveries be publicly verifiable.

For Profit Opportunities

It would seem that there would be abundant cash–in–hand market to incentivize the development, first of Earth Global Browser Monitors, using feeds from existing satellites, and then the establishment of other planetary global browsers and their satellite feeds as human economic activity moves outward, and as the public appetite for the product grows. To have a living planetary globe be recreated before your eyes in a form with which you can interactively react is one thing. But to understand what it would be like to experience phenomena visible from space from down on the surface “in the very thick of it” is another. As a teaching tool, global browsers need to be paired with on–location correspondences, from either manned, or unmanned surface videocams.

Joe Six–pack might even learn some geography in the process of being entertained! <MMM>

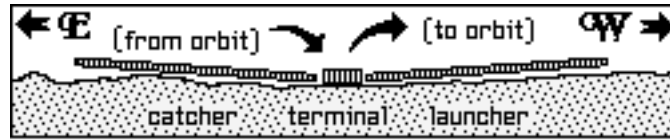
Man-rated Mass Drivers & Mass Catcher to & from Orbit



By Peter Kokh

In a previous article [MMM #121 DEC '98, “Lunar Intercity ‘Flights’ via the INTERCHUTE”] we sketched an idea for electromagnetic man-rated mass-driver / mass-catcher pairs to handle high volume intersettlement passenger traffic on the Moon via an automated suborbital shuttle system. Here we sketch the use of a similar system to get people on and off the Moon cheaply and safely – once an expensive infrastructure is discounted or amortized. As with the suborbital Interchute, this is a trick difficult to match on Mars where atmospheric interference would make it impossible to compensate with enough precision to make it work safely. Unlike the “Interchute” system in which each electromagnetic cannon will both throw and catch, for this to/from orbit traffic, as the directions (to/from) are opposite, not the same, there will need to be two cannons, one doing all the throwing, the other all the catching. It would be convenient to line them up back to back with a passenger terminal building in between. That would make it handy to process a shuttle that has just arrived for the return flight to space. A

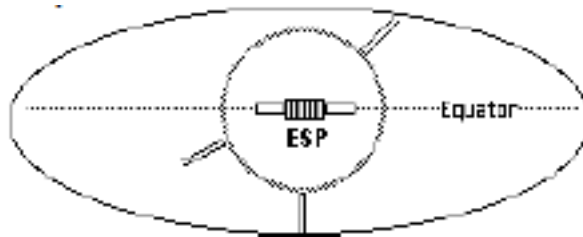
number of parking slips would be needed, as the order of arrival is certain not to be observed in the order of departure.



As traffic at this electromagnetic space port (ESP) grows, more parking slips will have to be added and provision for such expansion should be made in the original design. Parking is likely in a sky-sheltered area exposed to the vacuum. Nominal service can then be done in soft suits. Pressurized garages would be available for more labor-demanding service. Since the various craft would need to have the same diameter and cylindrical cross-section, this would make a standard garage slip-lock a sure thing.

The stakes are high. It would require corresponding space infrastructure, either in a precisely positioned orbit and oriented orbit, or near L1 or L2 Earth-Moon Lagrange points, whichever is the more stable and forgiving. It would also require onboard propulsion to taxi to the shifting station from its driver-catcher trajectory path and vice versa.

If the space transfer station is to be at L2, behind the Moon, the ESP would need to be sited on the Nearside Equator. If the space station is at L1, between Earth and the Moon, the ESP would have to be built on the Farside Equator in an intercrater plain – there are no maria smack on the Farside equator (a mare fill area in Aitken crater is the closest match), unlike the Nearside situation where there is an abundance of potential sites. Either option poses problems for the maintenance of the priceless Farside radio silence needed by radio astronomers and the S.E.T.I. Project. It would be near impossible to reproduce this radio silence anywhere else in the Solar



A potential disadvantage is that a driver-catcher must be on the equator – precisely so – whether handy or not to the locations of existing settlements. On the other hand, such an installation would be an economic boon to any settlements nearby or surely give rise to one if there were not.

The installation of such an ESP facility would speed up of the flow of immigration to the Lunar Frontier Territory (or Republic) as well as lower the cost per individual. A same cross-section, same total weight range cargo hold craft would greatly lower the cost of importing and exporting large items. In both ways, the inauguration of such a facility would mark a threshold of significant expansion of the lunar economy in total trade volume, tourist volume, and settled population. Inauguration of service will mark the attainment of a critical mass that changes the prospectus of the lunar frontier substantially.

Speed and momentum would differ only by a few percent from that of the proposed suborbital Interchute systems. So the length of the passenger-rated E-Mag cannons need be only slightly longer. There could conceivably be more than one such EMag spaceport, if the first was not sufficiently handy to all inhabited areas of the Moon. But the original cannons may not need to be doubled or tripled or more at the same site for a long time.

Loads could probably be received and sent at very short intervals with streamlining of the off-loading, shunting, and onloading operations, allowing perhaps hundreds of flights each way each day. Instead of duplicating the Electromagnetic Space Port at multiple locations around the Moon, it would be logical, at least early on, to make it THE hub of a global Interchute system. Both applications of passenger-rated electromagnetic driver-catchers seem destined for realization in tandem. One need not wait upon the other in this case, so long as the real estate and infrastructure needs of the other was considered in the planning of whichever comes first.

And no, there is no way the flight paths of Cans coming from and bound for orbit would infringe on the paths

of incoming and outgoing Interchute flights. That is especially guaranteed by making the same general location the hub for both to/from orbit traffic and for inter-settlement flights. The Interchute cannons might be best arrayed in a manner concentric to the ESP.

Interchutes would radiate out from the center but only in the directions called for by the location of high traffic generating locations. The Interchute Hub would be no more symmetric than the geographical array of settlements across the lunar globe. Such a Hub would deserve a special name like Port Luna, Lunaport, Lunar Global Gateway, Gateway Luna, Moon Central, Union Gateway, etc. It could just as easily be named after an individual prominent in the Lunar Republic's prehistory or early years, like Heinlein, or somebody yet unknown or even unborn.

Even if there were originally no nearby settlement or even any [other] economic reason to settle the Central Hub area, the steady rise in the transient population passing through it, and of the permanent population needed to service their needs, would give rise in time to a major city. Its primary industry would be running and servicing the Central Hub complex and all the people who pass through it.

Because the Central Hub will quickly become the gathering place on the Moon, it may well also become the entertainment, diversion and escape center, and be a magnet for such developments as:

- Global Trade Center and Export Showcase
- Major convention facilities and hotels
- Magnet shopping mall
- Duty-free or duty-low import shops
- Magnet specialty museums
- Magnet amusement park
- Groupie tourist traps cashing in on the traffic
- Headquarters for lunar excursion companies
- Headquarters for many all-Luna organizations
- Cluster of Earth nation and other Embassies
- Mars and Asteroid frontier recruiting agencies
- Network Broadcast/Telecast Center
- A major university
- A major medical center

[See MMM # 56 JUN 92, pp. 3-4, "Harbor & Town" republished in MMMC #10]

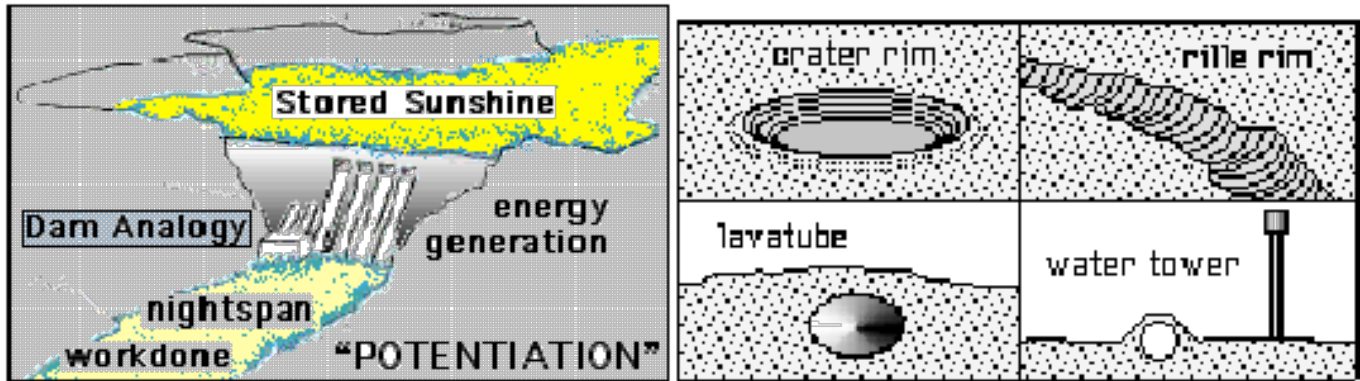
Other magnets needing maximum traffic to justify their construction or development costs will follow. However big the Hub Center gets, it will be the most homogenized melting pot on the globe, the least "typical", most cosmopolitan frontier city. In the wake of such a development, major conventional space ports may wane, although there will always be a need for such ports to accept and send cargoes and groups of people that the totally containerized Central Hub operations cannot handle as well as the space equivalent of "general aviation".

In turn, there will always be mineralogical, industrial, geological, geographic, scenic and other reasons for pre-established centers in other areas of the Moon to continue to thrive. More, a Central Interchute Hub need not preclude regional Interchute hubs.

Revenues: Paying the price tag of an ESP Hub Installation can be handled through Space-line can arrival, departure, parking and transfer (gate) fees, ticket counter leases, corporate hanger leases and user fees, and other "anchor tenant" contracts for companies wanting to provide service to the traffic (hotels, land excursion companies, merchants, outfitters, etc.).

The installation would not be built except under the expectation that it would be profitable within a given time frame. The greater the momentum slope of lunar economic development and immigration, the sooner the Electromagnetic Space Port is likely to become a reality. Running the operation could be the job of a Port Authority type entity with a Board of Directors responsible to the Lunar Frontier Government. The venerable "Port of New York Authority" might serve as a model, appropriate modifications and corrections being made, of course.

Others have thought of such a system in general terms. It is an idea that comes naturally enough, given familiarity with the concept of lunar mass drivers publicized by Gerard O'Neill. <MMM>



POTENTIATION: A Strategy for Getting through the Nightspan on the Moon’s Own Terms, P.Kokh
 [This article covers several ways to build up power during the two week long dayspan while the Sun shines full strength “24/14+” to provide ample energy for Lunans to get through the equally long nightspan. But here we post the part of the article that deals with Hydroelectric Power Plants on the Moon.]

“Potentiation”– A Strategy for Getting through the Nightspan on the Moon’s Own Terms

By Peter Kokh Presented at ISDC 1999, Houston. This idea originated with Myles A. Mullikin in 1989
Gravity Slopes & Hydroelectric Power

Gravity hills, slopes, gradients, wells: something is placed at the top of a slope, poised to create energy by being allowed to fall. On Earth, we dam up rivers at convenient constricting points. This creates a “head.” Water is allowed to spill over the dam in a controlled fashion, gathering momentum from its plunge, and using this momentum to spin turbines that run electric power generators.

No rivers on the Moon? No problem!

Wherever we place our outposts and settlements, we will need appreciable amounts of water: as an essential component of whatever minibiospheres we establish to reencradle ourselves; for food production; for drinking, washing, and hygiene; for use as recyclable reagents and handling media in industry. We will need a substantial water surplus, in part consisting of water being recycled and purified.

During dayspan, solar energy can be used to pump the water surplus uphill: nearby crater rims, rille shoulders, or the surface above lavatubes. At night this water is returned to the loop through tubes plunging to turbine generators downslope. Of course, at no time will the water be exposed to vacuum!

Of course, the amount of water available for this form of nightspan energy generation depends on the generosity of the settlement’s water endowment. Now that Lunar Prospector has confirmed the discovery of substantial water ice reserves at both lunar poles, this idea is not far-fetched.

It’s all about the “Head”

What about the low lunar gravity? Won’t that work against the idea? Well, Niagara Falls, which produces ample power, has a head of about 150 feet. To match that head, we’d have to have a reservoir 6 times as high above the generator turbines, or 900 feet up. Now some Crater rims are 10,000 feet or more above the crater floors. Many mare coastal sites are near high rampart mountains. These sites are advantaged by access to both major suites of regolith materials (highland soils rich in aluminum, calcium, and magnesium, and mare soils enriched in iron and titanium).

Even mid-mare sites in proximity to lavatubes will find ready “heads” of several hundred meters between the exposed surface and the floor of the tube underneath. Nor is a Niagara-equivalent head needed. There are many working low-head hydroelectric sites around the country in the 20 ft. range. Where there are no natural “heads” for reservoir placement, we can simply build water towers hundreds of feet high, using dayspan solar to pump them full.

Now let’s play with this idea. Dayspan sunshine can also be used to purify and treat the water in the reservoir – if the reservoir is covered with ultraviolet transparent quartz (pure silicon dioxide glass). Going a step further, dayspan sunshine can be used to electrolyze this stored treated water into oxygen and hydrogen.

After nightfall, the hydrogen and oxygen can be recombined in a bank of fuel cells, producing both energy on the spot, plus the water to fall downhill to the generator turbines, producing yet more energy. All these processes would have to be paced to extend this potential energy resource through the long nightspan.

Lunar Hydroelectric as sketched above, is the brainchild of Myles A. Mullikin, Lunar Reclamation Society cofounder. It was one of several of his major contributions to our "Prinzton" runner up entry in NSS's Space Habitat Design Competition during the winter of '88-'89.

Hydroelectric power on the Moon is the last thing that occurs to most people mulling the problem. But it turns out to be very realistic for any kind of outpost or settlement. No one pretends the amount of energy stored dayspan and produced during nightspan by a hydroelectric scheme will meet all the settlement's power needs. But it is one workable component of a mix pioneers will have up their sleeves. Planners should consider incorporating such interactive water storage into the settlement utility system.

MAM/PK

MMM #130 – November 1999

Of COASTS, HARBORS, & LIGHTHOUSES and, oh yes, LAVATUBES

By Peter Kokh

To build a bridge one must have knowledge,

To know where to build it one must have wisdom. –Charles V. De Vet

The difficult we do immediately.

The impossible takes a little longer. – Army Corps of Engineers

Lavatubes as "leeward lagoons"

When early exploring ships reached the coasts of the Americas and of Australia, they didn't put into shore just anywhere. They turned either right or left and sailed along the coast looking for a natural harbor that would shield their anchored ships from the wind and waves.

Before the first Apollo craft landed, our Lunar Orbiters had already found only cosmic storm washed coast-surface. The Lunar surface is alien and hostile and unwelcoming.

Today we know that this picture is not quite accurate. While the lunar surface is all "windward coast," it hides lavatubes that are "leeward" lagoons, "breakwater-protected" volumes of vacuum ready to serve as safe harbors, anchorages offering real refuge from the dangers of the cosmic ocean.

A natural Harbor along an otherwise unwelcoming coastline offers wind and wave free anchorage. Lunar Lavatubes offer analogous leeward shelter against the ravages of cosmic and solar weather.

Breakwater Outposts

Lavatubes are unlikely to offer dock slips to incoming space craft. Rather they offer volume that is thermally moderate, relatively free of moondust, and unexposed to Solar ultraviolet and Solar flares, "dry" from the constant micrometeorite rain, and free from cosmic rays. This is useful for settlement expansion, including industrial parks, warehousing, and square-footage intensive geponic agriculture for crops that do not do their best in hydroponics.

In these benign pre-shielded spaces, two things become much easier.

- **With no need for extra shielding**, inflatables, hybrid-rigid inflatables and unhardened rigid modules will all be at home, less expensive option in comparison with what will be needed on the exposed surface-coast. The lavatube roof/ceiling becomes a protective ramada or hanger for everything below.
- **Simple pressure suits will do.** Similarly, personnel occupied with tasks outside the habitat/lab and other structures within the lavatube need only unhardened pressure suits: lighter, easier to carry, and easier to work in.

But these user-friendly weather-free lagoons of the void out top, will not be the exclusive locations for lunar outposts. Some areas of the Moon rich in resources we will want to tap, are not handy to mare lavatubes. In such parts, there will be no ready alternative to digging in and covering up. But even in lavatube-endowed locations, there will be a need for a surface outpost and transfer station for goods and people on the surface near the lavatube entrance.

Entryside Service Installations: Division of Labor

Near the entry point to our lavatube main site, we will need a surface "interface" facility. A "construction camp" to prepare the rampway into the lavatube, or install an elevator if what we have is a "skylight" entrance. The surface post would then be the initial construction camp for deployment and construction within the lavatube.

Surface Facilities

As and if the demand for construction support winds down, a surface installation will still be needed to process visitors and goods, as a transportation mode transfer point and as a base for surface field work and expeditions. In addition, surface-shielded facilities will be needed at a spaceport location and as inns and service centers along major surface intersettlement transportation routes. While surface installations may outnumber occupied lavatubes, given that construction is simpler and easier within a lavatube environment, it is likely that overtime, perhaps a majority of Lunans will live in adopted lavatubes.

Ink-black Lavatubes can be sunlit via fiber-optic bundles connecting surface solar concentrators with in-tube light diffusion systems. For further reading on the possibilities, see MMM # 100 and 101, NOV & DEC, 1996, both online at www.asi.org/mmm/.

Lighthouses

On Earth we put lighthouses in two types of coastal locations: (1) on major headlands and peninsulas; ((2) at the entrances to major harbors. There does not seem to be an analogous situation to the former use, only for the latter. It would be a good idea to have a lunar version of a lighthouse at the entrance of a lavatube in any stage of occupation or adaptation for human purposes.

Even if Oregon L5's Lunar Lavatube Locator mission succeeds in jumping through all the hoops and over all the hurdles, it will have performed well if it maps even a small fraction of the Moon's population of intact and partially intact lavatubes. We will be discovering new ones, perhaps for generations. We might well put transponders near each identified entrance. But not all tubes will have open entrances. Nor are they navigational hazards, either for surface vehicles or spacecraft.

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MMM #136 - June 2000

An "All-In-One" Moon Resort

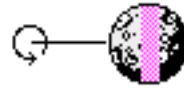
By Peter Kokh

You are a tycoon-entrepreneur, and you want to open a lunar resort-hotel for tourists regardless of whether or not there were other outposts already on the Moon or whether local industry had begun. Only very limited "easy" surface excursions would be possible, so you would want to find a location that "has it all." What would be a great location?

In "**Seven Wonders of the Moon.**" we divided all the Moon into four parts from a human point of view: the Crooknecks, where Earth is always high overhead, the **Postcardlands**, where Earth hangs suspended over the horizon, the **Obliviside**, from which Earth is never visible, and finally the **Peekaboos**:

"Straddling the "limb" of the lunar globe which forever keeps the same side turned towards Earth are "**the Peek-a-boos**". Because the Moon's axis is not perpendicular to its orbit around the Earth and because that orbit is somewhat eccentric and the Moon travels faster when nearer Earth and slower when further away, all the while rotating at a fixed rate, about 7° to either side of 90° East and 90° West are alternately turned towards Earth and away from Earth. The effect is that these areas are alternately part of Nearside or Farside."

These areas constitute a border are from which sometimes you see Earth, sometimes you don't. Hence the nickname - "the **Peekaboos**".



Now only somewhere in this globe-girdling strip, can tourists enjoy both of the Moon's celestial wonders. Everywhere else on the Moon, they can see one, but never the other.

- **The spectacle of the blue-white marbled Earth in the sky**, and at a comfortable elevation over the horizon – especially when the Sun is below the horizon.
- **The spectacle of the Milky Way** as revealed in unbelievable brilliance and glory in the darkest skies in the entire Solar System: no glare from Earth, no glare from the Sun – when both Earth and Sun are below the horizon.

But we must issue the following pair of disclaimers! While a lunar resort somewhere in the midst of the Peekaboos will offer both spectacles, there will be times when Earth is visible but the Sun is also above the horizon and uncomfortably near to Earth in the sky. And there will be times when Earth is below the horizon, but the Sun above, and glare from the surface will impede seeing the Milky Way.

Here's how we put it in "Seven WONDERS of the Moon" above.

The Milky Way. One of the lesser recognized ways in which our Earth environment continues to continue to degrade is urban nocturnal light pollution. There are millions of youth who have never seen the Milky Way.

"Libration"

Libration in latitude: as the Moon's axis is tilted slightly relative to the Earth's, each of its poles will seem to be tipped slightly toward the observer on Earth, in turn, over a four week cycle.

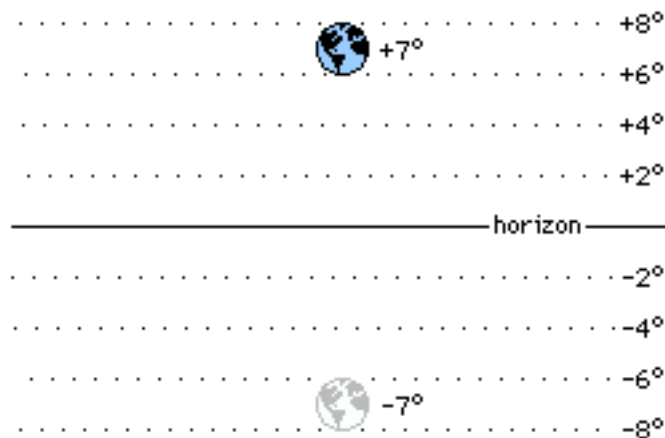
Libration of longitude: the Moon travel's at a slightly varying rate along its elliptical orbit, traveling faster when it is closer to Earth, slower when farther. Meanwhile the Moon's own rotation about its axis continues at an unvarying pace. So alternately, as seen from Earth, the Moon seems to be turned slightly eastward, then slightly westward. In each case we can peek about 7° past the mean 90° longitude over the edge of farside. These 14°-wide strips, from 83° to 97°, both East and West, are called the limbs, or in MMM-speak, the "Peekaboos". For as we can sometimes see around the edge, to observers there the Earth is sometimes above the horizon, sometimes not.

The combined effect of these two librations allows us to see some 59% of the Moon's surface from Earth, though only 50% at a time.

A good way to picture what happens is to imagine a very tall pole at the center of the Moon's Nearside, 0°/0°, whose mean position is pointed at Earth's center, but whose actual direction is sometimes above, sometimes below, sometimes to the East, sometimes to the West of that "anchor".

Antônio Cidadão has created a spectacular 133K animation illustrating libration along with oscillating distance, as seen from Earth. http://www.minervatech.u-net.com/moon/not_libr_ac.htm

This animation, covering one full lunation (lunar month, or in MMM-Speak, one full "sunth"), dramatically illustrates libration of both latitude (N-S) and of longitude (E-W). Notice also how the Moon's apparent size changes from perigee (its closest approach to Earth) to apogee (its furthest).



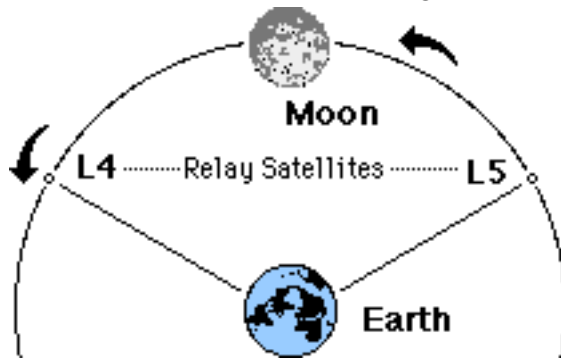
For those of us fortunate to live in or visit at least occasionally countryside areas well outside built-up populated areas, the sight of the Milky Way in dark star-bedazzled skies is unforgettable. But we glimpse it at the bottom of a wet, dusty atmospheric ocean. Even in mid-desert where on cold crisp nights the seeing is best, we are somewhat handicapped.

On the lunar surface, atmosphere is absent. But anywhere in the Nearside **Crooknecks** or **Post-cardlands**, and part of the time in the **Peekaboos**, there is the distracting brilliance of Earthlight that must be baffled not only from view, but from reflection on one's helmet visor.

It is in Farside during nightspan, both Earth and Sun below the horizon, that the Milky Way shines in full undampened, unchallenged glory. To look up from such a vantage point and scan this river of star clouds as it arches across the heavens from horizon to horizon is a treat no human has yet experienced. For those with soul enough to appreciate it, this awesome sight will be a, even "the reason" to visit, or settle in, Farside. Many will choose the peripheral Peekaboos along the limb, for in these areas one can enjoy both the Milky Way, and Earthrise/Earthset, alternately.

Even though these magnet celestial spectacles are each to be best enjoyed only at certain favorable times, the ability to offer both makes a Peekaboos location a must for an All-in-one Lunar Resort Hotel. But that leaves a lot of turf to consider.

Our other constraint -- only easy excursions will be supportable, especially if the Hotel is built prior to the establishment of a full lunar outpost able to provide logistical support of any tourist operations -- helps narrow the "doable" area greatly. We will want to site our Hotel in, or at the fringe of a level, easy-traverse mare plain. This will allow deployment of line-of-sight relay stations from the Hotel, out to at least 83°, E or W, from which Earth is always in sight.



Of course, we may already have established a communications relay satellite in one of the Moon's flanking Lagrange positions, L4 and or L5. But even if we do have an L4 or L5 relay, a mare or mare fringe site will allow excursions both east or west to get more favorable views of either great sky spectacle: Earth or the Milky Way.

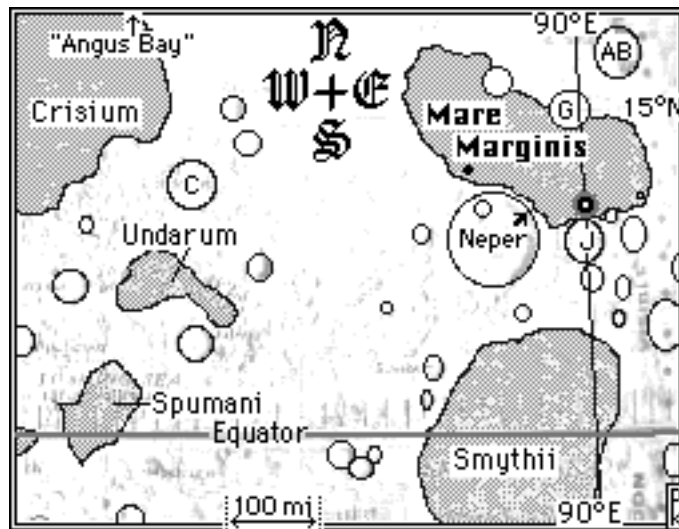
Along the western limb of Nearside, we don't find the ideal conditions. You could erect a Hotel at the extreme eastern fringe of Mare Orientalis, "Eastern Sea", the "Bullseye" in the center of the lead L4-ward face of the Moon as it travels about the Earth, or in its peripheral Lacus Veris, "True Lake". But in the first case, any travel to the east further into nearside would be extremely rough going over the ramparts of Mare Orientalis. In the second case, travel either east or west would be impeded. We will certainly see outposts and/or hotels in this area someday. But this is not the place for the "first."

On the eastern, L5-wards limb, SE of Mare Crisium, the "Sea of Crises" we find Mare Smythii astride the equator. Just north of "Smyth's Sea" and due east from Crisium, we find Mare Marginis, the "Border Sea". And well to the south, Mare Australe, the "South Sea" also straddles the limb.

Of these, Mare Marginis seems best to offer what we want:

- Level, smooth going to at least 7° in to a point from which Earth is always above the horizon
- Smooth going at least a few degrees deeper into Farside for optimum viewing of the Milky Way

MAP OF MARGINIS, NORTHERN SMYTHII, AND EASTERN CRISIUM



Sites in Mare Marginis: * "Peekaboo Resort"

* Earthlink Relay Station * Eastern vantage point * Neper Crater Lookout

LETTERED CRATERS: (C) Condorcet, (G) Goddard, (J) Jansky, (AB) Al Buruni.

["Angus Bay" is an Artemis Society nickname for Mare Anguis, NW of Mare Crisium]

If one were to put this Hotel at the location indicated on the map above, in mid-limb 90° East on the north shoulder of the 60 km [37 mi.] wide crater Jansky, you would have a moonscape spectacle at your doorstep. And it would be a fairly easy 80 km [50 mi] excursion to the rim of even larger and deeper crater Neper. At 113 km [70 mi.] wide, Neper is one of the Moon's "great craters," appreciably wider than 97 km [60 mi.] wide Copernicus, which, since it is much more easily observed from Earth, is considerably more famous.

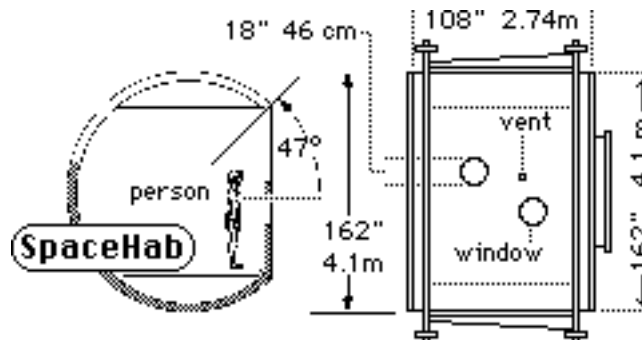
Neper, like Copernicus, has a central peak. Our suggested protocol [**Selenology**, AUG '89, pp. 18–21, "Extending the System of Lunar Nomenclature"] for naming such peaks is that if the crater bears the last name of an honored person, the central peak should bear his/her first name. In this case, Mt. John. John Neper (also known as John Napier), 1550–1617, was the Scottish mathematician who invented logarithms.

An easier traverse to the north would take us into the partially breached and mare-flooded crater Goddard, 80 km [50 mi.] wide. So a site in the Border Sea seems to offer the best of everything.

Even more reassuring is that a look at this whole section of the lunar globe suggests that as the Lunar Frontier more fully develops, Mare Marginis will not find itself left out in some backwater. A "highway" from the Mare Crisium – Mare Anguis area could pass through Mare Marginis, then through the highlands between Neper and Jansky into Mare Smythii, before heading ESE in the direction of Tsiolkovsky, and Mare Ingenii, deep in farside.

What might an early Moon Hotel look like?

Now that's a pretty wide open question! At this time, it would seem that the least expensive bare minimum would be a complex of **SpaceHab** modules outfitted to provide sleeping accommodations, a ward room for meals, a galley kitchen, communications, an infirmary, an EVA preparation room, etc. Plus a pressurized rover.



You would need at least that much to house and support a handful of hardy tourists, lead individual guided EVA “walks” in spacesuits, and take them on a few guided excursions to see the nearby “sights”. The current reference mission for the Artemis Project™ Commercial Moonbase is SpaceHab module-based. SpaceHab offers considerably more interior space than did the Apollo era Lunar Modules. Ganged in twos, threes, or larger complexes, we begin talking about real room. And they exist. They are pieces of actual, many-times tested hardware. Add to that their “affordability.”

As the International Space Station (ISS) becomes real, **station-type habitat modules** will come online, to offer further off-the-shelf choices. This selection will grow.

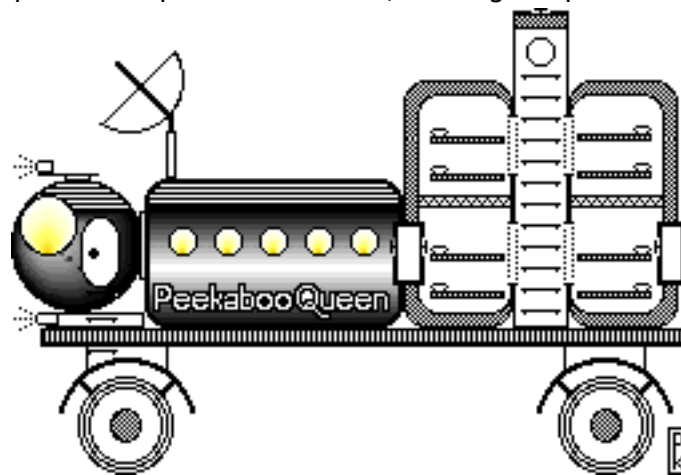
Inflatables should be available offering “big dumb volume” for a spacious central commons and for a lunar “gymnasium.” The ability to experiment with no-spacesuit lunar gravity in simple exercise, gymnastics, experimental sports, and even dance will make this a priority feature. Add on the capacity to make telecasts to Earth, and that will only strengthen the market. A plain inflatable could be fashioned as a sphere, cylinder (upright or on a side), or as a torus (the most stable footprint).



As we listed in our ISDC 91 Paper “Lunar Hostels: An Alternate Concept for Both First Beachheads and Secondary Outposts, Part II, The Hostel’s Share of the Workload” [See Above] such Big Dumb Volume is tailor-made for equipment-light, volume-hungry function spaces such as:

- bedroom quarters • exercise facilities
- lounge-chapel • visitor-made art displays
- dining area • lunar rock collections
- assembly area • etc.

Outlying interim “rest stop shelters” at places of scenic interest, for example, could be easily deployable **TransHab** type hybrid rigid-inflatable structures. For much greater versatility, and less duplication, one such could be part of the pressurized rover, offering sleep-aboard options.



With such a self-contained, if Spartan, motel on wheels, the Hotel could offer a far wider selection of land excursions, sooner. Properly designed for on location assembly of a few basic modules, such a “Wild, Wild Moon” type vehicle could be as essential as the Hotel itself. A smaller “rescue” coach-only vehicle would be a prudent backup.

As for the Hotel itself, more elaborate architectural possibilities will open up with on location building materials: **glass domes** for comfortable observation of the moonscape and heavens; or for a central Garden Atrium. Flowers might grow tall on the Moon. The lure of a walk through a floral forest could be irresistible to affluent newlyweds.

As permanent staff developed **lunar arts and crafts** (art glass, ceramics, regolith paintings, etc.) the decor of the hotel and its various inner spaces, could begin to take on a truly lunar ambiance. Guests could try their hand at new creations in these brand new media, choosing to take their works home as souvenirs, or leave them behind as inspirations and challenges to those who will follow.

Each of these phase by phase additions to the “Lunar Excursion Experience” will add to the market demand and encourage an ever growing flow of people to the Moon. That will make the development of lunar building materials and other industries ever more attractive.

In time, entrepreneur homesteaders will establish an enterprise zone nearby the hotel (if not in sight of it). They will come to offer new services and goods, both to the Hotel, and to the tourists that come to stay there. This will be a first humble step toward a cluster of tourist facilities such as we have at Estes Park, CO outside Rocky Mountain National Park; or at Gatlinburg, TN outside the Smoky Mountains National Park, or at the town of Wisconsin Dells near the river cliffs of that name.

And what a place for a summit conference of implacable foes -- a place where they will quickly see things in a whole new light, looking back at the precious Earth they share!

As population of the resort town grows, team sports and leagues will become possible, not for caricatures of well-known Earth sports, but for all new sports that are fun to play, and watch, and make sense in lunar “sixthweight.” This corner of the Moon will not just be in the news. It will be on the Home & Garden Channel and ESPN Sports. Suddenly, this out of the way place will be part of the Greater World.

To be sure, common wisdom suggests such a Hotel resort would follow, not precede, the establishment of a major science, “industry-breeder” outpost. But we are not at all sure that this common wisdom is on target. As illogical as it seems, tourism, not resources, may be the driver that first earns us a foothold on the Moon. Here is the scenario.

An Alternate Return to the Moon Scenario:

1. Tourism to low Earth orbit becomes affordable as new reusable rockets bring the cost of such flights down to the low hundreds of thousands of dollars, enough to sustain a “flow”.
2. Loop-the-Moon tours are an easy next step, requiring only refueling the shuttle-craft, a week’s extra provisions, and Spartan sleeping facilities. Once the cost for this is under a million dollars, the first flights will happen.
3. Resort Hotels in low Earth Orbit are built, to accommodate longer stays, more comfortable Earth viewing, and more zero-G sports and even dance. These hotels will slowly grow into sizable complexes, even offering artificial “gravity.”
4. The “Orbitels” become travel hubs.
5. Demand grows for lunar Surface Excursions
6. A small “growable” hotel complex is erected in Mare Marginis
7. Demand for more Hotel facilities leads to “on location” (those inept in English are wont to use the Latin equivalent “in situ”) processing of regolith into building materials to make expected continuing phases of hotel expansion financially “doable” and continue to provide sufficient “return on investment” to backers.
8. Availability of realized on location building materials attracts a consortium interested in developing Moon-based space energy schemes: lunar solar relay arrays, solar power satellites built of lunar materials, helium-3 mining
9. Other outposts -- industrial enterprises -- are built, first in the proximity of the Hotel and its incubator building material industries, then at other locations on the Moon.
10. An infrastructure for travel between outposts develops, both for mutual logistical support and for trade. Roads, even railroads, are built in an ever-growing network.
11. Hundreds, then thousands, then tens and eventually hundreds of thousands of pioneers come to the Moon and wind up staying, raising families in the booming settlements. The Moon becomes a Human World.
12. A Hotel built in the lunar Peekaboos to cater to the insatiable demands of the ultra affluent thus proves to be the unexpected Seed of major industrial and economic development of the Moon. Why? Because Tourist Dollars do not need justification by MBA bean counters. Tourism is built on affluence, not on economic needs or justification.

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The Black Sky "Blues"

THE BLACK SKY "BLUES" – Coping with "Black Sky Country" – By Peter Kokh

Foreword

On Earth we enjoy a brightly illuminated sky. If it isn't clear and blue, the clouds are bright. The darkest storm cloud is far brighter than pitch dark.

On Mars, the sky seems to be "salmon" hued, though there is one researcher who insists that this is only the case during and after dust storms. The point is that on Mars, as on Earth, the daytime sky is a source of diffused ambient light that makes viewing the landscapes easier. Earth and Mars are "bright sky worlds," a gift of their atmospheres.

On the airless Moon, however, the sky is pitch black during dayspan. In the glare of the unfiltered Sun the naked eye cannot see even the brightest star. During the near-side nightspan, Earthlight will cast a glare from up to eighty times as bright as that of full moonlight on Earth. Even a partially lit Earth will also blot out most of the stars. Only on the lunar farside, forever turned away from Earth, do the stars come out during nightspan – and with a brilliance we cannot imagine. But at no time anywhere on the Moon is the sky itself "bright."

We've all grown up with the night. We don't mind it. Nighttime darkness is only temporary. With dawn comes welcome visual relief. On the Moon, that relief never comes. Our pioneers will be transplanting themselves to "Black Sky Country." And that can have long term psychological consequences.

With the black sky even at "high noon", the contrast volume between surface and sky is intense. Shadows are bottomless visual pits. This will cause some eyestrain. Of course, this will be more of a problem for those who spend a lot of time out on the surface – in the "out-vac". But it will affect those who spend most of their time in pressurized spaces as well: in what they see through various types of "windows" (vidscreens, periscopic picture windows, etc.); it may affect "skylights" as well.

Coping with Black Skies

To the extent that the "Black Sky Blues" do become a subtle morale problem, and this may differ from individual to individual, ways of providing deserve serious attention. Here are a few, we can think of for starters (and we invite readers to send in additional suggestions):

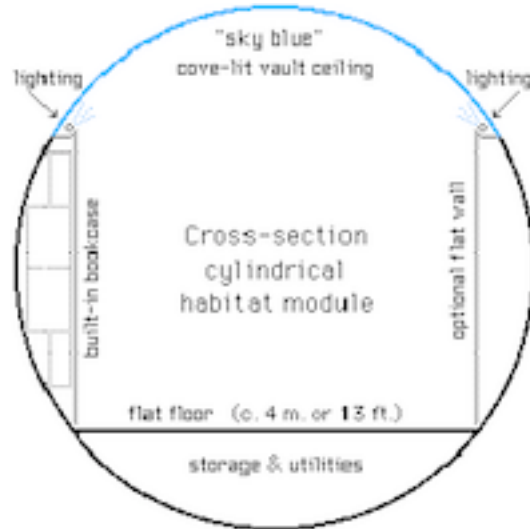
- **Electronic Windows** – Whether we call them telescreens, visiscreens, or something else, electronic images of the surface scene outside offer, for good as well as mischief, the opportunity to be manipulated. The viewer may be able to select a sky color and brightness to his or her liking. The viewer, much like an Internet browser, would then "interpret" the black areas at the top of the picture accordingly. Pick a light gray to go with the moon tones, or a smoky blue. Or, if you're a visiting Martian pioneer, a dusty salmon. Those homesick for Earth can pick a brilliant blue. The idea is not to deceive oneself but to prevent eyestrain – if it has become a personal problem.
- **Spacesuit Helmet Visors** – Would it be possible to give the visor some differentially reflective coating that would "brighten" the sky, even if just a bit, without interfering with clarity of visibility of the moonscape? We throw out the challenge. If this proves feasible, could we do something similar with regular windows and periscopic picture windows (Z-views)?
- **Skylights & Clerestory Windows;** On Earth, water vapor in the atmosphere scatters the sun's rays so that light seems to come uniformly from all directions. Our atmosphere is a natural "diffuser" with a bluish cast. For those windows meant to bring in light but not necessarily the views, could we produce some sort of frosted and translucent, but not transparent, glass pane that will not only let in sunlight but appear itself to be bright, giving the illusion of a bright sky beyond? Again we but throw out the challenge. One might experiment by holding up various kinds of existing glass and diffusers to a streetlight against the dark nighttime sky.

Windows, skylights, and clerestories of this type will be desirable not just for private homes but for sunlit pressurized streets and other "middoor" spaces, sports facilities, highway waysides, etc. Passive light scattering panes to the extent that they present a satisfying illusion of a bright sky could become standard, or at least common.

Without real experimentation, we would not pretend to guess what will work best. But we should be trying a lot of things, including foamed glass, aerogel, special coatings or laminate layers, etc.

Meanwhile, this standby: Some may not want to wait for such *tromp d'oeuil* developments, or disdain them as dishonest. And it may turn out that none of these suggestions will be possible to realize in a truly satisfying way.

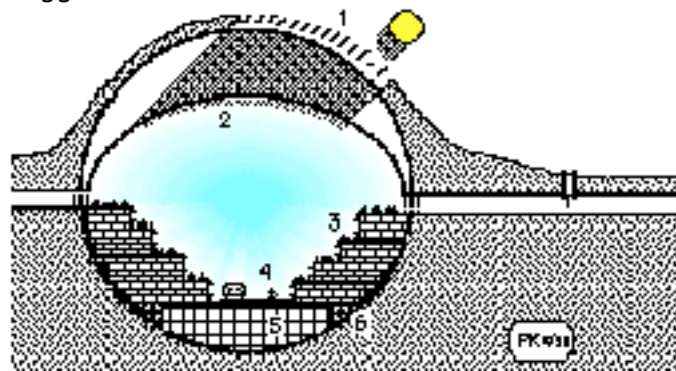
There is another, simpler way. Pressurized habitat structures and modules will commonly have curved surfaces. We'll need to install flat floors, of course, but the curved ceilings of spheres, cylinders, and toruses present an opportunity. Finish them with a light-absorbing matte texture and illuminate them with cove lighting. Give the finish – or the light source – a subtle blue cast, and *Voilà*, the appearance of blue sky. That these vaults offer greater ceiling height will only enhance the effect.



We can in effect, recreate the familiar blue sky indoors on the Moon. On Earth, where all we have to do is step outside, this hardly seems like a worth-while extra expenditure. On the Moon, suggestively bluish cove-lit vault ceilings may become the norm.

Cove lighting, especially if it is really “sky-bright”, will reduce the need for other lighting: floor and table lamps, wall sconces, and especially ceiling lights and chandeliers. Strong indirect ambient light reflected everywhere off the vault ceiling from cove light strips hidden from view will create a positive psychological “atmosphere”.

It’s understandable if some residents might prefer the flat, white ceilings they are familiar with on Earth and to get their daily dosage of blue skies in common “middoor” spaces such as pressurized roadway tubes. Below is a suggestive illustration from MMM # 53 March ‘92.



THE RESIDENTIAL STREET (“HOOD”) AS THE MODULE

Cross-Section of cylindrical module 40m x 200 m:

- [1] shield louvers let in sunlight; [2] suspended sky-blue diffusing “sky”-air pressure same on both sides; [3] terraced residential housing with rooftop gardens; [4] thoroughfare running the length of the (neighbor)’hood; [5] light industry, shopping, offices and schools; [6] conduits for utilities.

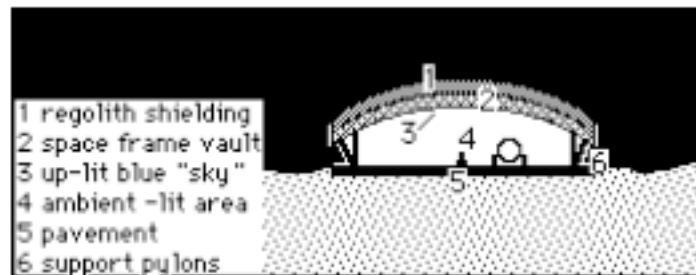
At first, roadway tubes will be of a much more modest scale, of course. But other “middoor” spaces (pressurized common spaces neither inside private quarters nor “out-vac” on the surface) such as school recreation spaces, public squares, sports arenas, and “park and picnic areas within agricultural modules all are prime opportunities for faux blue sky ceilings. During the two week-long

nightspan daylight (on an artificial 24 hour schedule) could be simulated by using electric cove lighting aimed at such vault ceilings. During the equally long dayspan, sunlight could be indirectly channeled by mirrors to reflect on the vault–ceilings full–time, or shuttered to simulate night conditions on a 24 hour schedule.

Blue Sky Simulations Out–vac

What about simulating blue skies outside the settlements, out on the surface? This might be very desirable for frequent inter–settlement travelers, truckers, and others whether they spend a lot of time in such conditions or not. Certainly, one could design emergency solar flare shed vaults and other covered roadsides, even if unpressurized, lit from below, thus providing “bright skies” of a sort, whether they be blue, white, or light gray.

One can foresee a day when many thousands of people live on the Moon in several settlements. There might then be one or more heavily traveled surface corridors. These could be covered with shielding vaults lit from below, open to the vacuum. Such lunar “superhighways” would make for safer, more comfortable driving conditions, day or night.



Someday, settlements may be built within great megastructures with soaring ceilings. These too could be designed to offer bright blue skies. But meanwhile, the use of cove–lit vault ceilings in habitat and other interconnected settlement modules will go a long way to shake those “Black Sky Blues” or at least help inoculate the settler pioneers against the accumulative visual deficits of the “magnificent desolation” of the lunar terrain.

But hopefully, someone will pick up on the other challenges we’ve put forth, of individually tunable “browser–like” video screens, special light scattering glazing options, and smart helmet visors.

The “Black Sky Blues” is something we need to take seriously. It poses an acculturation challenge unique to the Moon and other airless worlds which future Martian settlers will not have to face.

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MMM #140 – November 2000



Transportation & Town Sites

TRANSPORTATION & TOWN SITES By Peter Kokh

Home Planet Habits

A careful glance at any atlas will reveal a significant number of city and town sites that owe their location to geographic features that anchor transportation routes. Along the coast, there are many cities with natural harbors, some of these at the mouths or estuaries of navigable rivers (New York, Boston, Norfolk). Inland, perhaps a majority of cities and towns are located on lake shores or riverbanks. Among the latter, are many that have been founded at special points along their rivers: waterfalls and rapids (Minneapolis, Cedar Rapids, IA), fording points (Rockford, IL), easy portage points to parallel rivers (Portage, WI), and at major river junctions (Pittsburgh) or deltas (New Orleans). Others sit at an end of a lake around which surface traffic is diverted (Chicago!). Still others guard mountain passes serving as gateways (Denver). And then there are those secondary and tertiary sites that spring up wherever two roads or a road and a river cross. Not to forget railroad junctions! Perhaps not many people give the reasons for town location much thought. But they don’t just plop down out of the sky.

On Shoreless, Riverless, Trackless Worlds

Interesting, perhaps. But what relevance does any of this have to the Moon or Mars? Neither world has actual oceans or lakes or rivers. Nor are there any roads or railroads across their barren trackless wastes. Ah! Perhaps not in the same explicit and developed sense as on Earth. But both worlds are full of features that will attract, redirect, or otherwise constrain transportation corridors and increase or decrease the suitability for townsite location.

Coasts, Seas, Lakes

The Moon does have coasts, even if its seas are of congealed lava floods rather than water. Maybe we won't have to change transportation modes when we go from lunar sea to lunar highland as we do on Earth (boat to car or train), though in time there may be vehicles specialized for both. More significant is the fact that there is a chemical makeup interface at the lunar coasts on the Moon, just as on Earth. Instead of "ground" to water, we go from soil richer in aluminum, calcium, and magnesium to soil richer in iron and titanium. Lunar Mare/Highland coasts are the prime locations for industrial town sites, affording access to both major chemical suites of lunar regolith.

But not all coastal sites are created equal. Some lunar coast areas will afford easier overland access through their rim ramparts into the highland hinterland "interiors" than others. That is, some coastal sites will offer breaks, passes, or easy ramps up into the higher, more mountainous and more crater-pocked highlands. They have the advantage.

Some lunar maria or seas are landlocked or isolated: Crisium, Marginis, Smythii, Humboldtianum, Orientalis, Ingenii, Moscoviensis, etc. But on the nearside, most mare lava plains are interconnected: Oceanus Procellarum and Mare Frigoris, Imbrium, Serenitatis, Tranquilitatis, Fecunditatis, Nectaris, Nubium, Humorum etc. In some cases, neighboring seas are conjoined along broad stretches which leaves a lot of room for choosing one's route. In other cases, there are areas where it is much easier to traverse from one to the other. In these cases, the likely transportation corridors narrow considerably. Even a rudimentary Moon map or nearside photo will illustrate several such instances.

One especially narrow natural corridor links Mare Frigoris in the far north to the northern coast of great Mare Imbrium via the Alpine Valley. It is a no-brainer to predict the rise of settlements at both "valley gates."

Surrounding some seas or maria we find a number of "satellite" lava floods, sometimes named as lesser seas (Mare Undarum, Mare Spumans southeast of Mare Crisium, Mare Anguis [Greg Bennett's "Angus Bay"] northeast of Crisium) or lakes (Lacus Veris near Mare Orientalis): but many are nameless, e.g. northwest of Crisium. Perhaps these lakes will attract transportation corridors, becoming easy-going respites from otherwise more difficult highland traverses. We need to pour through the orbital maps and topography and altimetry data to define the best routes, ones needing the least bulldozing and grading, less cuts and fills.

On the maria themselves, as flat as they are in general, there are here and there impediments to easy going which one must either negotiate or detour around. There are some craters, even a few large ones, with their rubble strewn rims. There are also crater ruins or reefs, pre-lava flow craters that are only partially flooded. These are common in M. Smythii.

More important to consider are the lava flow features themselves. Flow fronts can be a hundred or more meters higher than older flows beyond. And then there are the sinuous rilles universally interpreted as collapsed lavatubes of especially large dimensions. Recall the pictures of Hadley Rille from the Apollo 15 mission. We must either negotiate their slopes or detour around them. In some cases we will be lucky to find natural bridges, actually uncollapsed lavatube sections. There are several of these along the Hyginus Rille in Mare Vaporum in central Nearside. The larger, most central of these bridges is likely to attract both highway location and, as an uncollapsed lavatube section, settlement. Put a town and an assured transportation corridor together and you get a prosperous trading center too.

As to the lavatubes we strongly expect to find wherever there are lava floods, some of them, all else being equal, will make more logical settlement sites than others, simply on the basis of how conveniently they are individually located in relation to transportation corridors selected on topographical grounds. Eventually, all "buildable" lavatubes may be occupied, but the best placed ones will be settled first. If we have both a well-argued transportation corridor map, and an orbital radar map of lavatube sites, we could put together a good short list of prime sites.

Surveyors of the most logical routes for the highways and railroads and pipelines of the settled Moon ahead must pay attention to all these things.

Thus 2 things will shape the lunar globe:

1. **Where** the various resources are
2. **How** we get materials, goods, services, and people back and forth between them

To determine a lunar outpost, even the first one, without paying attention to these other considerations risks setting the course of lunar development on a dead end course. Those determined to start at the South Pole rather than the North, risk just such an outcome. More about that next month.

The Northern Ocean & other Martian “Seas”

Mars, like the Moon, has no bodies of liquid surface water. Unlike the Moon, it once did. The seas of Mars are dried up real seas, not seas of frozen water. Here as on the Moon, we are likely to find clear chemical interfaces at the “coasts.” Here also we will find easier or more difficult entry into the surrounding higher hinterland. Here as on the Moon, we will find some obstacles in traversing these seas, but they will be obstacles carved by water rather than by lava floods.

All of these considerations will constrain transportation routes and help determine future town sites. But there is this difference. On Mars, there is the real technical possibility, the ethical and moral debate aside, of filling this ocean and these seas with water again. Those who dismiss this possibility will dare to build settlements on the dry ocean floor, much as some Israelis, who dismiss the possibility of Palestinian statehood, dare to build settlements on the West Bank. In either case, no one can demand that those in question not take that risk. But the risk remains. And much as diehard Israelis hope that these settlements will provide a barrier to the recreation of a Palestinian state, future “Reds” on Mars, as they have come to be called, are likely to found settlements and build roads to them on the dry ocean bottom in hopes that this will pose a political fait accompli to prevent refilling of the ocean basin.

The other significant depressions are the Argyre and Hellas basins, the latter by far the deeper and most extensive. If one were to pick and choose areas to flood with precious water, Hellas is the most logical, the vast northern ocean bed the most ambitious. Arguing against the flooding of Hellas is the fact that as the lowest depression on Mars, it enjoys the marginally highest air pressure -- it is still very thin. It is unlikely anyone alive today will see either eventuality. Speaking of Hellas, by pure chance, the greatest seaport in the fictional Mars (Barsoom) of Edgar Rice Burroughs was Helium. Both words come from the Greek but are from different roots. In Greek, Hellas is Greece, Helios is the Sun.

The great Martian lava floods poured out from volcano throats, building up shield volcanoes layer upon layer analogous to, but far, far larger and taller than Mauna Kea/Mauna Loa (the Island of Hawaii): the trio of Ascraeus Mons, Pavonis Mons, and Arsia Mons, plus the mighty Olympus. In contrast, the lunar lava floods oozed out of the fractured bottoms of great impact basins and spread out evenly. In both worlds these lava floods are likely to be riddled with lavatubes, ready made shelter for settlements, industrial operations, warehousing and archiving. In both cases these offer safe and secure settlement sites. On Mars, Pavonis Mons, being by chance astride the equator, assumes an enormous advantage, its west slope the best location in the solar system for a launch track, its summit the best anchor in the solar system for a possible space elevator. Add in an extensive maze of lavatubes and Pavonis Mons is the most assured major urban site in the solar system beyond Earth.

The Crated Highlands of Moon and Mars

The crater-pocked highlands of the Moon and Mars are strikingly similar in appearance and morphology. In both cases there are areas that are saturated with craters large enough to discourage travel. In both cases there are “intercrater plains” that would seem to be easier going. Whether we set about to survey future roads, railroads, or pipelines, we need to pay very close attention to the altimetry and topography data in picking the easiest most sensible routes. The routes selected will in turn decide which potential town sites see the light of day. Even in the case of significant highly localized mineral deposits, sites on or near logical transportation corridors are the likely to be developed.

If one looks at the best photographic atlases of the Moon and Mars, it is almost possible to plot the most negotiable routes now. But we won't want to cast our choices in concrete before seeing the very high resolution data. Terrain that looks very smooth in medium resolution, can be revealed to be strewn with boulders of significant size on further investigation. The whole length of all proposed route options must be looked at carefully, their various pluses and minuses weighed before making a decision.

Happily, on the Moon and Mars we have the chance to identify and preplan these corridors in advance of settlement, and thus in advance of politics. On Earth, it is all too frequent that a less logical

routing is picked to bow before political pressure from already established settlements along one of the proposed routes. Lay out the transportation map first, then choose the settlement sites. On the Moon and Mars the jury on successful establishment of human civilization will always be out. We cannot afford to make mistakes for political reasons.

The Poles and their Approaches

Both on the Moon and Mars, the significance of the poles is that they hold known water reserves. Even if, in the case of the Moon, we find excess hydrogen rather than water ice, it amounts to the same thing. Oxygen being everywhere in the rocks, the essential special ingredient of water is hydrogen.

On both worlds, thirsty circumpolar and equatorial settlement prospects may rest on tapping these polar reserves. On Mars, some non-polar areas are blessed with abundant permafrost in the soil. Siting a settlement in or adjacent to such areas will be very attractive IF these reserves are shown to be sufficiently extensive, practical to tap, and sweet rather than saline. Only "ground truth" probing can determine this. In advance of on site testing, we can only sketch the vague boundaries of permafrost areas of high promise, all else being equal, and we can do that only if we succeed in brainstorming and flying instruments to detect and map subsurface permafrost from orbit. This is a high priority for which there is as yet almost no demand among the planetary scientists interested in less practical "knowledge".

Meanwhile, early planning is wise to start with brainstorming how to get polar water ice to other areas of the globes of the Moon and Mars. If we truck it, we need roads. If we send it by rail, we need railroads. If we pipe it, we need pipeline routes. In all three cases we need reasonably easy routes. These preselected routes will determine the corridors along which secondary settlements make sense.

Heated water pipelines or aqueducts seem logical for Mars. On the Moon where surface temperatures range to both higher and lower extremes, it would make much more sense to refine the water ice along with any immixed carbon oxide ices (highly likely given their cometary origin) into Methane CH₄, and oxygen, piping both gases in carefully separated parallel pipelines to user market terminals. At the various destinations, these gases can be recombined to produce water and useful carbon dioxide in a process that recovers the energy put into refining as a most useful bonus. That makes this operation a logical choice for nightspan scheduling when availability of energy is lowest.

Thus the paths of water movement away from the poles on both Moon and Mars will do much to fill in the maps of both globes with the details of human civilization. On Mars, human-built canals will be as significant to both economy and biosphere as the imaginary ones of Percival Lowell.

Starting Now - a Project for 2001 - "frontier feature annotated" Moon and Mars maps

We already have good enough altimetry and topographical data on both the Moon and Mars to begin now to predict at least some off the more logical transportation corridors on both, as well as narrow down where they will intersect. Who will do this? Not NASA, which uncommitted to settlement, is not about to indulge in such foolishness. This is a job for groups of volunteers, perhaps dedicated chapters of NSS, the Mars Society, and the Moon Society.

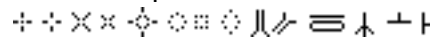
Railroad routes will be more demanding than roadways to plot as they have more demanding grade constraints, even in lunar gravity, perhaps especially so as traction is reduced along with gravity while momentum remains the same. We will want the highest resolution altimetry and topography data to select wisely from route options of competing merit.

Pipelines can use pumping stations, and gas pipelines are less sensitive to grade than liquid ones. but, we will want to plan either with pump stations conveniently serviceable from parallel roads.

In carefully, slowly, filling up our maps and globes with promising routes and nodes, we should not neglect nearby scenic attractions of opportunity. There is a lot worth seeing on the Moon and Mars. What people get to see most commonly, will be those features nearest to travel routes established for trade and commerce on topographic grounds. We may find logical names for some of these scenic overlooks.

As routes, intersections, nodes and hubs are identified, we might give the more prominent of the settlement sites suggested by this network provisional imagination-feeding names. In many cases we can do this quite logically by basing these names on nearby features with internationally established names, using suffixes or modifiers like ford, bridge, pass, gap, valley, gate, head, delta, outlet, lake, heights, point, junction, portage, ridge etc.

We needn't name them all, only those where a logical name is rather obvious. The other sites can be marked with mapping symbols for the nature of their advantage, the symbol sized according to apparent strength of that advantage. For example:



And Voilà! two suddenly more "human" worlds. Science fiction writers would have a shared convergent plateau from which to build further. The rest of us, pouring over such "frontier feature annotated" Moon and Mars maps and globes would sense worlds the outlines of whose human futures could already be glimpsed through the fog of events still in the future.

Of course, none of these names can be more than provisional "working designations" pending the approval or disapproval of the eventual settlers themselves. The point is that simply naming places on the Moon or Mars with carefully reasoned high settlement potential will work to advance the day such settlement becomes a reality. <MMM>

MMM #151 - December 2001

Engaging the Surface with Moonsuits instead of Spacesuits "Mother Nature has a Dress Code!"

By Peter Kokh

In last month's issue (MMM #150 NOV '01) we began our discussion of learning how to be "at home" on the Moon with articles on domesticating regolith, getting comfortable with overnighing, and learning to live with the Moon's natural rhythms. But there is much more to this agenda, and we pick up the litany this month. First on the list: lunar space suits!

Space Suits have traditionally been designed to protect us from alien environments, not to engage those environments on a "let's make ourselves at home" basis. These would seem to be just empty and cheap words at first reaction, but let's play with the idea, follow it, and see if it leads somewhere new.

When NASA sent astronauts to the Moon, it was with suits designed to protect them from a poorly understood and understandably "alien" environment. They did have a good understanding of the thermal loads and heat-management problem, of the radiation flux at the Moon's surface, and some inkling of the uncooperative character of the pervasive moon dust. In designing the suits, it was essential to err on the side of overprotection. After all, the scientific goals of these missions were definitely secondary to the overriding directive to "bring 'em back alive!"

When we return to the Moon, the controlling directive will be to learn how to stay. Breaking the systems engineering and psychological barriers of overnighing will be at the top of the list of milestones in this campaign. And that will mean that we must have suits that can do more than handle the moderate "midmorning" solar heating loads. They must be up to handling the higher heat loads of "high noon" and of the lunar "afternoon" period (remember that from sun up to sun down takes a full 14 and three quarter standard Earth days). But in order to do outside routine and emergency housekeeping, maintenance, and other chores during the equally long sub-bitter cold night spans, the suits must have a controllable heating capacity with high reliability. Proper insulation against heat loss by radiation to the black sky will be essential. So even without the extra features we will identify as desirable below, the suits for the return missions will have to be improved, at least in thermal management capacity, over those of the Apollo era.

So much for the obvious. What we want to talk about in this article is the need for Moon Suits that go beyond such improved basics. We need to put to work the tremendous electronic tele-sensing abilities that have become doable in the three decades since the Apollo feats.

Smart Suits

For safety' sake and to maximize the odds of safe return, or rescue if that should ever be necessary, we can build a number of sensors and computer processor chips into our new "smart" moonsuits. The wearer should have at his or her demand, all of the following kinds of vital information:

- Power reserves and time available at current energy consumption rates
- Oxygen reserves and time remaining at current consumption rates
- Thermal management stress loads as a function of capacity
- Radiation flux with screen becoming activated when flux exceeds normal range
- Built-in GPS (global positioning system) distance covered (GPS track) over the horizon landmark locator (GPS calculator) direct return route distance (GPS calculator)
- warning when the capacity of any system approaches the "point of no return" level

The readouts from these devices could be either constantly visible, or projected on the visor “heads up” area either when activated by a voice command or automatically when a caution or emergency condition develops. No one needs to be unnecessarily distracted by boring confirmations that everything is “functioning within normal parameters,” but information that requires attention, must have a way to get attention. An alternative to a heads up display for less critical information would be a sleeve readout device.

A transponder belongs in every moonsuit. It could broadcast its signals via satellite or via a relay at one of the Lagrange point station (L1, L2, L4, L5 -- according to one’s location on the Moon’s surface). To personnel at the outpost or vehicle from which the suited excursion originated, the wearer’s position would be monitored (as a backup system in addition to the suit’s own GPS monitor.) If there was sign of inactivity lasting long enough to cause concern, or a cut off in transmission, or a signal that a suit function had failed or been compromised (e.g. even slow depressurization from suit puncture), the wearer’s location would be pinpointed.

Additionally, if someone sensed s/he was in trouble, the whereabouts of any nearby persons also out on the surface could be ascertained, and a route to their location plotted or a signal sent.

One of the tradeoffs of such safety features is that if the Big Brother aspect. There are times when one may want to be alone -- just him/herself, the moonscapes, and his/her thoughts. One should be able to turnoff a transponder, but with a double switch to prevent accidental disconnects.

These kinds of “Guardian Angel” features are well within current technology limits. They would make us more safely “at home” on the Moon. There is more we can do, so stay tuned.

Smart Visors

Not only can we thus greatly improve moonsuit safety features as described above, we also have it within our power to greatly enhance the wearer’s perception of his/her environment. In comparison to the “Native Scout” expert clue recognition abilities that moonsuit wearers will “put on” when they don their suits, the Apollo moonwalkers had all the clueless sensory capacity of city slicker dudes. No offense intended, of course! They were all genuine heroes of the first rank who did all they could and more with the tools we gave them.

Our point is that it is not enough just to be able to look through a helmet visor with the naked eye. Moon-scape’s are notoriously monochromatic and the immense information that they bear comes across to the naked eye as a monotonous blur of seemingly trivial details. Smart Visors and other electronic sensory enhancers could change all that, and allow the wearer to see an immense variety of significant information of scientific, prospecting, or other value that normally fades into the monochrome overload.

Smart Visors and other sensory enhancers will allow future moonwalkers to “engage” the Moon as never before, by letting them see and sense information clues that “naked eyesight” just can’t detect, notice, or pick out. Here are just some of the possibilities that are within our means.

- Infrared scanning of the ink black shadows and kneemount shadow penetrating spotlights
- Phosphorescence sensors
- Picking other humans out of the background
- Exaggeration of slight and subtle color difference
- Telescopic zoom-in capacity
- Sensors that sniff any outgassing in the area
- range finder (distance to near horizon features can be greatly misjudged by the naked eye according to Apollo EVA experience)
- Tevel horizon guide (in low gravity, one’s ability to detect slight slopes is impaired)
- Filters that enhance visibility through any dust electrostatically suspended over the surface
- Alert-alarm and activation of laser spotlights when sensors in combination with expert recognition systems detect special spectral and reflectivity signatures of minerals. etc. on a field science or prospecting watch list
- Alert alarms for any motion in the visual field
- Alert alarms for any motion in the shadows
- Other expert recognition programs
- Major computing power to analyze inputs (the computer design should address the clumsy gloved fingers vs. keypad issue using voice recognition software and other means, be able to calculate mineral and element abundances of samples, and, using GPS and range-finding data draw simple but functional “map” guides)

We’ve probably missed a lot of other possibilities and if readers have some suggestions to add to this list they are encouraged to contact MMM by mail or by email <KokhMMM@aol.com>

But the list above will give some indication of the enormous potential there is to use today’s electronic wizardry to let future moonwalkers be vastly more attune with and aware of their environment. “Engaging the Moon on its own terms” is what we are after -- the ability to be able to see critical information normally lost in the visual monotony as if one were an experienced native-born scout.

Wearability and Mobility Issues

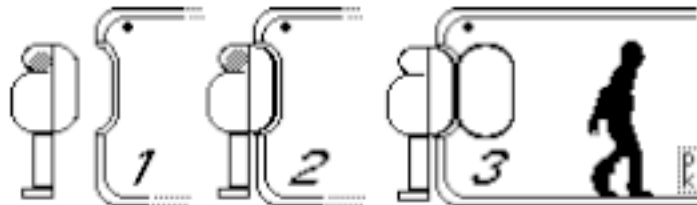
Comfort and Convenience were justifiably secondary concerns from the designers and fabricators of the Apollo moonsuits. One can put up with most anything on a temporary basis, so long as the discomfort or inconvenience is not great enough to compromise the work at hand. But now we are going back to the Moon, intending to stay, intending to make ourselves at home. Field scientists (geologists, mineralogists, etc.) and prospectors and others will be out on the surface for longer periods, and repeatedly. In such circumstances, discomfort and inconvenience risks compromising the work at hand.

What do we need here? Surely suits that are easy to put on and easy to take off without assistance. And suits that do not require pre-breathing special air mixtures. We need to make it so wearing proper apparel to go outside on the Moon is no more of a big deal than wearing proper apparel for rain, cold, wind, or snow is for us on Earth. In short we need suits that protect us without a lot of bother and drama.

We shouldn't attempt to find an ideal design that offers such features in isolation from the even more important issue of dust control. The use of conventional airlocks will inexorably lead to the immigration of annoying and trouble making amounts of fine powdery moon dust into pressurized habitats, labs, workspaces, and other facilities. Previously we have proposed a solution prefigured in illustrations by the great lunar outpost illustrator, Pat Rawlings -- the clamshell-back or turtle-back space-suit. We described its operation in the MMM #89 article cited at the bottom of this article.

"Pat Rawlings did the illustrations Ben Bova's 1989 book "Welcome to Moonbase" [Ballantine Books, New York, ISBN 0-345-32859-0] has elsewhere illustrated a much superior dust-control approach. The cover of "Lunar Bases and Space Activities of the 21st Century" [W.W. Mendell, Editor; Lunar and Planetary Institute, Houston 1985, ISBN 0-942862-02-3] shows personnel wearing what I have come to call the **"Turtleback" suit**, in which an oval hardshell backpack covers the torso and back of helmet. This backpack is hinged on one side, and entry to the suit is made through the opening.

"In prerelease conceptual illustrations Rawlings did for the David Lee Zlatoff/Disney/ABC '91 movie "Plymouth"(still the only science fiction film ever made about settlement and the idea of using lunar resources), there are sketches of turtleback conformal airlocks (my word) into which this specially designed backpack makes a sealed connection, then swings open, allowing the incoming astronaut to (pulling his hands and arms out of the suit sleeves) reach back and up through the opening to grab a bar above the inner door of the lock and pull himself out of the suit and into the habitat. The suit and most of its dust remains outside, perhaps to be stored automatically on an adjacent rack. Whether Rawlings himself ever thought through his artistic concept this far, or further, is unknown to this writer. But we want to give him full credit."



Next we need suits which are as light as they can be made, and agile! There are probably things we can do with both the boots and the gloves to make the wearer more sure-footed in all types of lunar terrain, and more dexterous in handling samples, climbing, making repairs or performing service operations. If our moonsuits constrict our mobility and agility, making us "all feet and all thumbs," wearing them will exhaust us all too quickly, decreasing both the amount and the quality of work accomplished.

The amount of quality work that gets done per person hour is the name of the game. In time, it will also be a question of enabling people to go out on the surface to engage in field hobbies and out-vac individual or team sports. If we meet the needs of scientists and prospectors, we will enable those with an "outdoors" recreational needs as well.

Out-vac exercise and sports activity of any kind will depend on the invention and debugging of a lightweight, supple pressure suit that can handle the heat and perspiration loads generated. If total out-vac exposure times are kept to an acceptable accumulative minimum, radiation protection can be minimized. Given the considerable benefit and boost to overall settler morale, the development of such a suit is sure to be on the collective front burner. Such suits will have to have many "smart" features we have described above.

For both work and recreation, overall morale enhancement is the real prize. Upon this morale hangs the long term viability of lunar settlement. Now unlike providing sensory enhancement, providing

EZ-wear suits that allow maximum mobility, agility, and dexterity is a goal much more easily described than realized.

Our intent is not to give clues as how we can meet these goals, but to define what these goals should be. NASA has long been aware of the shortcomings of its spacesuits and for a time was funding two different teams to come up with replacement designs. Then the work stopped. There may have been some Agency dissatisfaction with the results being achieved in the two projects underway. Each was promising advantages, but by means that were mutually incompatible so that all the proposed advantages could apparently not be realized in either design. But we think that the real reason for shelving these two projects was Neanderthal budget-cutting, by those who could not see the big picture, or cared.

This kind of R&D needs to be directed by a commercial enterprise that has a stake in the results and in the quality and quantity of work done on the Moon. For now, brainstorming and paper studies of radical new moonsuit designs that meet these objectives are about all we can hope to see -- until some intently for-profit consortium has a eureka dream that "there's (a) gold(mine) in those (gray) hills!"

Active Helper Systems

One could also imagine a number of "helper systems" that would enhance the surface excursion experience even further. Power tool plug-ins Set II. In addition to tools useful in investigating rocks and minerals (drills, saws, core samplers, etc.) and various glove and boot accessories, we could "plug in" more exotic, even "handier" tools. How about an automatic laser device that would leave "Reeses Pieces" "hot spots" that would remain detectable for a few hours to assist the wearer in retracing steps especially in jumbled and confusing terrain?

Or how about a retrievable tethered mini "scamperer" probe that could reach spots (up/down cliffs and escarpments, inside crevices and clefts, etc. and other hard or inconvenient to reach areas) and either analyze what it detected and send back the data or pick up and return promising samples? The second season team at the Mars Society simulation outpost on Devon island discovered the surprising usefulness of such critters. They experimented with 100 m and 200 m tethers (leashes, anyone?)

We'd be delighted to hear from readers about more such active helper systems. Think of them as productivity maximizers and safety insurers.

The Fremen Stillsuits of Dune/Arakis

Okay, so that's a bad title in as much as those who do not allow the pleasures and escapes of science fiction into their lives will have no clue of what it means. To Sci-Fi fans, no explanation is needed. So let's try again.

Accommodating Human "Needs"

Our suits of the Apollo moonwalkers had provision for urination -- a definite improvement over the one Alan Shepherd wore less than a decade earlier. But these suits were made to enable stays of a few hours at most. We'll want to do some trial and error experimentation with alternatives that will cover our butts, so to speak, for longer periods under both normal and distressed conditions (er when it's Immodium time). Accommodating for regular bowel function (other than by the "low residue diets" fed to the Apollo crews) within the tight confines of a space suit will pose quite a challenge, but one we must meet sooner or later, so why not sooner?

Truly long-duration suits would have the capacity to recycle urine into drinking water, and for the uninitiated, that as the gist of the first subtitle for this section. Now that will make many queasy but it is no more than a very accelerated version of what happens in nature. So if this makes you ill at ease, get with the program!

Suits will have controls to adjust the gas composition of the air, and scrubbers to remove or recycle exhaled carbon dioxide. To create a "micro" biosphere system to handle all this indefinitely without frequent fresh inputs would seem an impossible challenge. Fortunately, some people relish "impossible" challenges. We predict breakthroughs in this area -- in time, and not by an "agency."

The ultimate backup system would be a "noninvasive" vital signs telemetry system. That is a nearer term goal, one we should find easier to meet.

Wrap Up - "Moonskin"

Actually, we are all born with a space suit of sorts -- our skin, which is one of the most important yet least appreciated of the body's essential systems. The skin works to keep our body fluids in and contaminants out. But this natural integument evolved to meet the challenges of our terrestrial environment.

Now as we move out into spaces and places beyond our native atmosphere, we do not have the time to let “evolution” do its work in spinning us an improved formfitting protection layer.

But the way the skin works without encumbering us to assist our mobility, agility and dexterity is the model we must hold before us in designing our “moonskins” the suits that will let us be at home on the Moon as if we were native. With the right outerwear, we could operate freely on the Moon’s surface and be attentive of all the clues the moonscapes hold. Well designed moonsuits well let us “belong” in our adopted homeworld. **MMM**

MMM #152 – February 2002

Lighthouse Network for Travelers

By Peter Kokh

In MMM # 151 DEC ‘01, pp. 3–6 “Engaging the Surface with Moonsuits instead of Spacesuits” we suggested that Lunar GPS units be standard equipment. Yet, the Moon being the unforgiving environment that it is, redundancy is the wisest policy.

So we pose the question: how would “lost” or location/direction–confused travelers, explorers, prospectors, and other people in the field find their way to their destination, or back home, if for some reason their GPS unit was not working, or the system was down (satellite failure)?

An updated and Moon–adapted analog of the time–revered lighthouse network along the coastlines of Earth’s oceans and Great Lakes might be useful, particularly in analogous “coastal” areas of the Moon. The Moon’s “seas” -- plains of congealed lava that fill great impact basins -- are bordered by impact basin ramparts and highlands with intermittent high points or “headlands.” Travelers taking coast–hugging routes could benefit from a chain of well–placed lighthouses. In time, a network of such beacons could be placed on high points along cross–highland routes as well.

By “Lighthouse” we mean:

Before we go any further in this seemingly romantic reverie, let’s make clear what we do and do not mean by a lunar “lighthouse.” These would not be manned, nor would they be eternally “lit” as are our terrestrial analogs. Nor need they be as large.

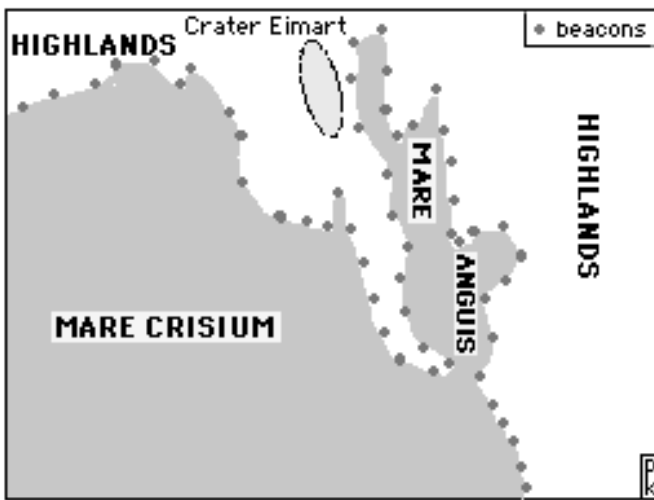
The lunar “lighthouse” we envision normally sits passive, “on call” when needed. An omnidirectional radio signal from a confused traveler would awaken any lighthouses in line–of sight. Each would then send out a directional homing beacon signal that would contain a “signature” identifying it to the traveler to help in determining his/her location. A visible light pulse could also be emitted when the lighthouse was in darkness or shadow.

These units would have solar panels to keep batteries charged, with enough of a charge to work when needed during the long nightspan stretches. Once in place, they would operate “on call” indefinitely without tending, and without grid connections.

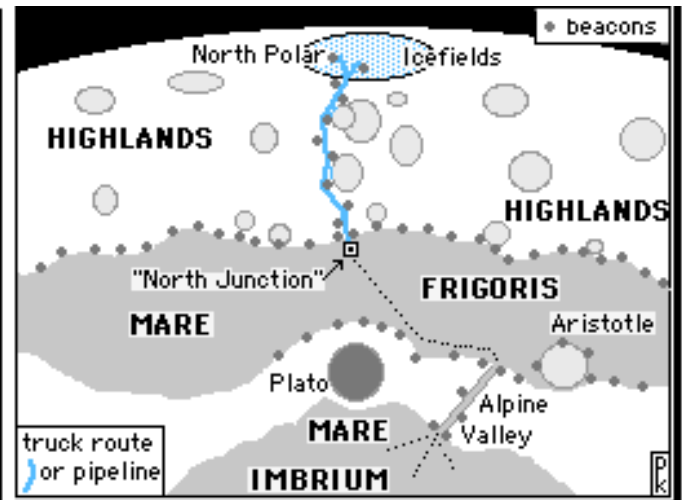
Samples of placement:

We have made line sketches of two areas where such networks might be useful in the earliest frontier period (proposed) areas of early settlement. [Discounting the Poles as totally atypical regions that are likely to be dead–ends.]

1. the coastlines of “Angus Bay” (Mare Anguis (Sea of Serpents) and adjoining NE coast of Mare Crisium (Sea of Crises)
2. the northern coastline of Mare Frigoris (Sea of Cold), a prime settlement location (“North Junction”) -- and high points along one possible cross–highland route to the North Polar Icefields and the “white gold” they contain.



Beacons along the Crisium & Anguis "coasts"



Beacons along the Frigoris "coast" & Alpine Valley

Such automated "lighthouse" beacons could be small and relatively lightweight which would help in deployment. The first explorers to blaze any trail through "virgin" terrain would set them at surveyed high points so that the network would grow steadily with the expansion of "explored" terrain.

Could we package such beacons in inflatable tetrahedrons (we don't want them to roll back downhill much less down the opposite slope) so that we could hurl them precisely to their intended perches without having to scale hills ourselves? Within such an envelope, the equipment package would be self-upright itself, then deflate the cushioning envelope.

Along level terrain routes with no real high points, beacons can be hoisted up telescoping pylons -- after all, on the Moon the horizons are much closer than on the larger Earth. On this windless low-G world, such pylons could be very lightweight.

Such a system could be the prime carrier of communications and data in, from, and to the deep Farside where we will want to maintain high radio quiet for Radio Telescopes. It's all part of making the Moon a friendlier place to call "home." <MMM/>

MMM #161 - December 2002

Tourist Clusters on the Moon

By Peter Kokh

Foreword

In MMM #136, JUNE 2000, pages 5-8, we wrote about an "All-in-one Moon Resort." This article described the general advantages of various locations on the Moon from the viewpoint of visibility of Earth above the horizon, concluding that locations on the limb, where due to libration effects, Earth was sometimes just above and sometimes just below the horizon offered the "best of both worlds," that is, the advantages of Nearside locations along with the advantages of a Farside one.

The article also traced a surprising scenario, which is becoming more and more plausible as time goes on: tourism, not industrial development of lunar resources, may pace the opening of the Moon. What follows is a fresh, shorter, look at how tourist facilities are likely to multiply on the Moon.

The Dawn of Lunar Tourism

We are, alas, still a long way from returning human pioneers to the surface of the Moon. There are no NASA plans to do so - all such previous studies gathering dust on the shelves per instructions from Congress - and amorphous plans of China, India, and Japan to put people on the Moon cannot yet be taken seriously, none of these nations having yet put an astronaut in orbit. The Artemis Project would set up a first commercial Moonbase, and indeed, this seems a more plausible eventuality than Congress reversing course and ordering NASA to shake a leg.

Everyone waits for someone else to put precursor pieces of the terracing puzzle in place, however, and so we do not seem to be making any real progress. That none of the would be movers and shakers has a critical amount of seed money is the harsh reality, of course.

We have all been quick to herald the opening of the Space Tourist age with the ISS visits of Dennis Tito and Mark Shuttleworth, the first “kids on the block” to come up with icebreaking money. Efforts to get additional camera-toting commoners into space through “creative financing” have so far not succeeded. That’s to be expected. The more we rely on multiparty financing, the more failure points we introduce into the plan.

Yet interest of “ordinary people” in space tourism remains quite high. Once someone succeeds in bringing down the ticket price by a factor of ten, then a hundred, the floodgates will first crack, then shatter. Regular traffic will lead to dedicated, if spartan, orbital tourist quarters. As prices continue to come down, and the number of ticket purchasers grows, whole new orbital tourist centers will be developed, unconnected to ISS.

Once we have a dedicated tourist shuttle, it simply requires refueling and reprovisioning that craft to send it and its passengers on a no-land loop-the-Moon up-front-and personal venture following the default path taken by the limping Apollo 13 craft. Indeed, as we have pointed out previously, tourists could skim over the Moon’s farside before the next humans return to the Moon’s surface. It is a simple fact that landing on the Moon, and then returning, requires additional hardware and fuel. See “Lunar Overflight Tours” – pp. 22–26 above.]

But where do we go from here? In the MMM #136 article cited above, we suggested that a dedicated surface “hotel” complex might be developed in Mare Marginis (or some other “limb” location.) But the actual step by step development of lunar surface tourism may start quite humbly, without any surface facilities at all. The first tourist lander craft will serve as a self-contained hotel, exactly as the Apollo Lunar Excursion Modules not only brought astronauts to the surface, and then returned them safely to lunar orbit rendezvous, but served as their “camp” while on the surface. Such a craft could set down just about anywhere on the Moon’s surface, perhaps visiting a different location on each trip. This “butterfly” strategy would encourage repeat visits by some of the well-heeled early Moon tourists. And as anyone in business knows, the repeat customer is a principal mainstay of success.

First Dedicated Tourist Surface Facilities

From this point in time, it seems obvious that the first permanent habitat on the Moon will be a module (with auxiliary equipment) manufactured on Earth and transported to the Moon’s surface. There is simply no other way to get started. We cannot rule out the possibility that once the facility is field-tested, debugged, run through a full lunar dayspan–nightspace cycle and judged “operational” by advance crews, its intended design use will be for tourists. After all, we do need to make the first outpost earn money, and tourism is certainly a promising source for a steady revenue stream.

However, this approach would seem to be a dead end one. Bringing pre-manufactured ready-to-deploy-and-use habitat space from Earth is forbiddingly expensive. There will be no way to get beyond the “rugged campsite stage” without first developing the capacity to produce lunar building materials, and modules, from processed local moon dust – regolith. So while hosting occasional tourist visitors will be an important way to raise capital for testbed lunar industrial experiments, the principal and regular occupants of a first outpost will need to be those pioneering the early industrialization route. Only when we are ready to begin manufacturing, and assembling, and outfitting expansion habitat and function space from modules manufactured on site, can surface tourism grow.

Scattered Tourist Sites vs. Tourist Clusters

Here on Earth, there is a seemingly inexhaustible number and variety of tourist destinations, facilities, and activities from which to choose. In fact, this has been the case since at least the middle ages, but has never been so manifold and so accessible to the general traveling public as today. Yet while we can fly here today, there tomorrow, on a butterfly itinerary that samples many locations, a mainstay of surface tourism, especially for the driving public, has been the tourist cluster: one general destination that offers a great variety of facilities and activities.

The tourist cluster comes in many sizes. There are the mega-clusters of Orlando and Las Vegas, of course. But we are thinking of the many smaller clusters around the country whose development preceded these modern day wonders. Inspired by my own experience, four “gateway” clusters come to mind.

- **Wisconsin Dells, WI** – gateway to the scenic Dells of the Wisconsin River
- **Estes Park, CO** – gateway to Rocky Mountain National Park
- **Gatlinburg, TN** – gateway to the Smoky Mountains National Park
- **Cave City, KY** – gateway to Mammoth Cave National Park & many more similar clusters

1st Outpost – 1st Tourist Surface Itinerary Synergy

Now on the Moon, we will, in time, have clusters of tourist facilities and for-profit attractions (frequently disparaged as “tourist traps”) at gateways to some of the Moon’s more outstanding scenic attractions: the crater Copernicus, approaches to the Alpine Valley, for examples.

But it seems certain that the very first lunar tourist cluster will grow up in close proximity to the first lunar commercial-industrial outpost as it gradually develops into a true settlement.

Tourism requires support facilities and support services and people “on location” to man them. However, it will be a while before the tourist stream becomes a steady one and requires the “day job” attention of support cadre on location. In the beginning, tourists will arrive in small groups at infrequent intervals. Tour group leaders familiar with the outpost and the lay of the surroundings can themselves provide much of the support.

They will have the Outpost to visit, and make the tour of surrounding support facilities: solar arrays, fuel tank farms, construction sites, road-building sites, regolith harvesting and mining sites, processing facilities. And, of course, the local scenic high points.

As the stream of visitors grows in both numbers and frequency, one can imagine a definite symbiosis emerging between the tour operators and the Outpost and its staff. For example, an additional pressurized motor coach/crew transport could be paid for on a time-share basis by both the Tour Operator and the Outpost Agency and bring real benefits to both. New roads serving new scenic attractions as well as new mining or processing sites could be built. Tour Operator need for automated self-help rest stops would seem to be a made-in-heaven match for the Outpost’s needs for a network of service garages/ emergency flare shelters. In short, we can expect a real, if partial, synergy between the driving needs of Tour Operators and the driving needs of an Outpost aggressively expanding in both size, staff, and diversity of activities.

That there will be some friction and disagreements will not discourage such a partnership. Only an Outpost that aggressively seeks to expand along for-profit vectors has any real chance of morphing into a real settlement. And we all know from experience here on Earth how important an economic driver tourism can become.

Location, Location, Location

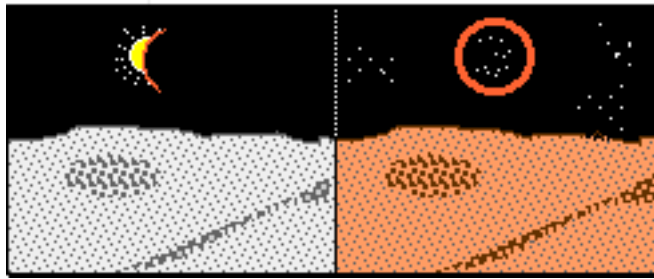
It could happen that the first outpost-settlement-to-be will be quite close to a major scenic attraction. But it is more likely that scenic advantages will be an important but secondary consideration in site selection. Yes, to support a variety of marketable services, we will want a photogenic site, one with interesting moonscapes, and one from which Earth hangs in the sky not uncomfortably far above the horizon (in “The Postcardlands.”) It is also likely that the outpost planners and site-pickers will have the foresight to realize that a mare-highland “coastal” site will offer the best strategic advantages for industrialization: access to both mare and highland suites of lunar regolith resources. And such a site will be much more interesting from a tourist point of view: vistas of great plains along with a setting of nearby mare basin rampart mountains.

Two such site proposals are Greg Bennett’s “Angus Bay” (commonly known as Mare Anguis, Sea of Serpents, an irregular winding mare-filled bay off the NE “coast” of Mare Crisium) and our own “North Junction” proposal for an outpost along the north coast of Mare Frigoris at the overland gateway to the north polar ice fields. Both offer comfortable Earth viewing and a mix of plains, mountain ramparts and craters.

In time, as diversification of the economy leads to the spread of human presence to many distant locations on the Moon, more scenic attractions will become accessible. A first “service station / flare shed / inn could lead to a cluster of tourist facilities of which providing access to the flagship scenic attraction in the area will be only the first.

In clusters, whether of tourist facilities, fast food restaurants, or automobile dealers, everybody benefits from increased traffic. The cluster provides something for everybody within a relatively small area, so more time can be spent on enjoyable activities, less on traveling from one to the other. Industrial diversification keyed to special ore concentrations may lead, but tourism will help build the future map of the humanized Moon.

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Eclipses: the Lunar Experience

ECLIPSES: THE LUNAR EXPERIENCE

By Peter Kokh

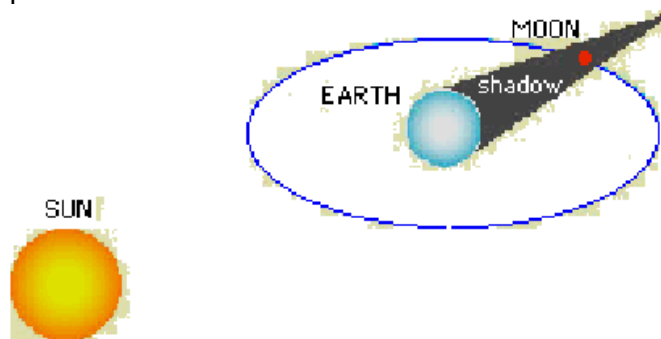
Every now and then, Earth-facing moonscapes take on the hues of a dimly lit Mars. But there will be no mistaking where you are. In the sky in place of Earth will be a black hole outlined with a ring of orange tones with only one ten-thousandth the brilliance of sunlight. And in that black hole, clusters of lights, Earth's cities and fires, dotting otherwise dark continents. It is **Umbra**.

Thursday, May 15th, 2003, there will be a total eclipse of the Moon, visible from all of the Continental United States and Hawaii, and from most of the rest of the world except Asia and Australia. For information about this event, go to: <http://www.netspeed.com.au/minnah/2003/2003-1.html>

For an Eclipse Computer that will tell you when (and where in the sky) the eclipse is viewable in your area, go to: <http://aa.usno.navy.mil/data/docs/LunarEclipse.htm>

Most everyone has seen a total lunar eclipse at one time or another. They aren't all that rare. But no one has ever experienced such an event from the Moon's surface. What would the experience be like? What would we see in the lunar heavens? How would it transform the appearance of the surrounding moonscape?

For observers on the Moon, what we Earth-dwellers experience as an eclipse of the Moon, will for them, be an eclipse of the Sun, our home star disappearing behind the Earth. So the phenomenon that they would/will experience will bear closer comparison to the one that those fortunate enough to have seen a total solar eclipse on Earth have felt.



Shown: Moon passing thru Shadow Cone (Umbra)

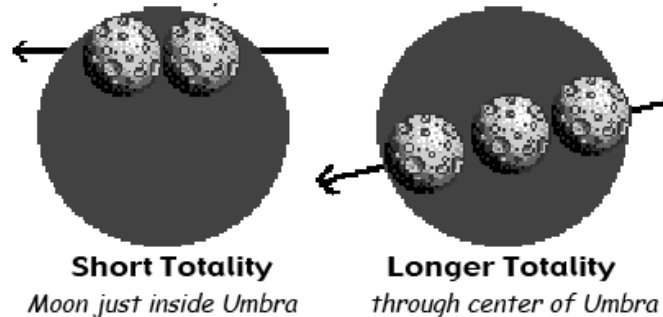
Let's try to visualize and feel the sight and impressions that future Lunan pioneers can anticipate.

Comparisons

Those of you fortunate enough to have witnessed totality in a total solar eclipse (anything even a tad short of totality counts as zilch – yes, there is that much difference) were probably as little prepared for the overwhelming effect of the experience on oneself as I was, when I saw my first from Minot, North Dakota in February 1978. The sky darkens gradually, suddenly going black, as the Sun disappears and the stars come out, in what should be bright daylight. Where the Sun had been there appears in its place a very black hole in the sky surrounded by a ring of flames, the corona. Meanwhile the air temperature drops some tens of degrees, and an eerie silence falls. For many first time witnesses, the experience is so unexpectedly transfixing that the goal of seeing yet another total eclipse suddenly soars out of nowhere to somewhere near the top of one's personal life agenda. For me, that quest next led to Bratsk, Siberia in late August, 1981.

Much of the magic of this experience arises out of an unlikely coincidence. The size and distance of the Moon makes its apparent size vary from just smaller to just a bit larger than the apparent size of the Sun. Total solar eclipses occur in the latter case. Because of the close approximation in apparent size, totality is brief, commonly two minutes give or take, with a maximum of seven.

But from the Moon, Earth's apparent diameter is some three and a half times as great as that of the Sun. When the Sun disappears behind the edge of the Earth, it will take quite a bit longer before it peeks out from the other side. Totality on the Moon can last some three hours.



Moon just inside Umbra through center of Umbra

For us on Earth, during totality, the Sun's flaming corona can be seen surrounding the black hole in the sky that is the Earth. From the Moon, the Sun's corona will also be eclipsed for most of totality. However, the black Earth will sprout its own "coronalet" as sunlight beaming down upon the hemisphere of Earth turned away from the Moon, lights up the dust in the atmosphere. This light is refracted into the shadow cone. Portions of the Moon passing closer to the edge of the Umbra will be brighter, those closest to the mid-umbra darker. Clouds and volcanic dust in Earth's atmosphere will also have an effect so the actual appearance, brightness, colors and color variation will change throughout the event and differ from eclipse to eclipse.

Watchers on the Moon will see an unbroken ring of sunsets and sunrises, much less brilliant than the Sun's corona, but also much larger in diameter, and an awesome sight. Stars hidden by the Sun's glare will reappear in the sky. The glow from this 'coronalet' will repaint the Moon's surface in very unmoonlike hues. For the pioneers, it will be a magical time in which they might imagine themselves transported to deep twilight on Mars! The direction and length of shadows will not change from what they would be if the Earth were not blocking the Sun. But the edges of shadows will be much fuzzier, contrasts less sharp. Familiar moonscapes will reveal themselves in this whole new light.

For crews, tourists, and settlers on the Moon's nearside, it will be an unforgettable experience. While for them, this will be a "solar" eclipse, the real show will be on the Moon's surface, with the show in the sky just completing the "Landscape." That's in contrast to the experience of solar eclipses on Earth where the main event is in the sky. For a treatment of the coloration and brightness-darkness of the Moon during Umbra, see "Danjon Scale."

<http://sunearth.gsfc.nasa.gov/eclipse/OH/Danjon.html>

Timing and Frequency

How often do these events occur? The Moon's orbit around Earth is tipped some 5° to Earth's orbit around the Sun, so the Moon spends most of the time either above or below the plane of Earth's orbit and does not pass through Earth's shadow every orbit. There can be as many as three eclipses a year, as few as zero. Only a third are total. While one seldom sees either lunar or solar eclipses noted on calendars – (just the phases of the Moon) "umbra" dates are likely to be noted on Lunan calendars. Where on the Moon Eclipses will be visible

The Umbra Experience is only visible on the Earthfacing side of the Moon. That means that the Sky Show of black Earth outlined by the ruddy sunrise-sunset ring of dust-refracted sunlight will be high overhead in the central areas of nearside (the "crooknecks") and at more comfortable elevations above the horizon nearer the limbs (in the "postcardlands"). Some events may be visible in the limb regions, others not, depending on the angle of libration (variance from facing Earth dead-on) at the time.

Both the proposed Angus Bay and North Junction sites will offer comfortable viewing, with Earth some 20–30° above the horizons, with shadows of mid-range length. In contrast, at a site near the center of nearside, not only would the sky show be directly overhead (zenith), but there would be no shadows, it being a high "un-noon" situation. Tourists coming from Earth to experience the umbra will

head to areas closer to, or in the limb region. Umbra will occur early in dayspan for areas east of the Earth-facing meridian, at mid-dayspan along that meridian, and later in dayspan for areas to the west. Impact on frontier culture

The Moon is a world of gray shades, overwhelmingly so. Indeed, Lunans will be challenged to infuse their homes and settlement areas with color to make up for the sensory deprivation that greets them out on the surface. To be able to view familiar out-vac surroundings through the filter of sunlight refracted through Earth's dusty sunrises and sunsets will bring periodic relief and delight. Umbra will also provide the best viewing of the many clusters of city lights on Earth's nightside, framed in the sunrise-sunset ring.

The hours-long event will be occasion enough to let kids out of school, even workers. Umbra could even become a holiday of sorts. For these pioneers, who will have given up much that we take for granted, who can begrudge them this periodic pleasure. Add to that, that each Umbra will be different, and the same event will be experienced differently in various places on the Moon.

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Postscript: Umbra-clad moonscapes

Where one is on the Moon will make quite a difference. The relative brightness of the brighter highlands and darker maria (lava plains or "seas") will be much the same. The reddish umbra light may make some areas stand out. Shadows will be in reduced contrast with the umbra-lit areas and have softened edges (owing to the greater diameter of Earth's sunrise-sunset ring than the angular size of the sun's disk), but in the same direction.

During a short totality, portions of the Moon nearest the edge of the umbra shadow remain relatively bright, where as portions deeper within the umbra are considerably darker. For pioneers, the brightness or darkness of the eclipse "twilight" and of surrounding moonscapes will depend on one's position on nearside relative to the umbra center.

Popular vantage points – The spectacle will be more comfortably viewed the further one is from the center of nearside (the closer to the horizon Earth sits in the lunar "sky.") Vantage points that include both mare and highland terrain in the foreground will be more interesting. "Experts" and Umbra devotees may seek out special vantage points. **Visiting Tourists**

People will come to the Moon from Earth, even from Mars, to experience the brief spectacle. Because of demand, prices for Lunar Eclipse Excursions flights to the Moon, or even just to loop around during the event, may be higher than other flights. An eclipse experience would highlight a visit The Spectacle of Earth's city lights. I think that the Nearside Umbra experience (by far the best to view Earth's city lights) should be added to the list, expanding it to eight, or supplanting the Straight Wall. The others: (Nearside) Copernicus (or other major crater), Alpine Valley, Lavatubes; (Farside) Tsiolkovsky, and the heavenly splendor of the Milky Way.

The Spectacle of Earth's city lights

In MMM # 69 OCT '93, p 8-9, "7 Wonders of the Moon," [MMM C #10] I listed my personal picks which included the Nearside Spectacle of Earth in the heavens. But I was thinking of viewing Earth under normal phase conditions – the Bright Blue Marble. I think that the Nearside Umbra experience (far the best to view Earth's city lights) should be added to the list, expanding it to eight, or supplanting the Straight Wall. The others: (Nearside) Copernicus (or other major crater), Alpine Valley, Lavatubes, (Farside) Tsiolkovsky, Milky Way splendor in the heavens. **MMM**

MMM #170 – November 2003



LUNAR ROADS Early Frontier Highways on the Moon

By Peter Kokh

The Moon has a regolith blanketed surface of impact-pulverized rock rubble and powder of variegated

graytones. There has been no weathering by wind or water and the pristine impact powder on the Moon remains angular and gritty. There are no rivers, not even dry ones (wadis or arroyos) to cross, no need to provide drainage.

On the other hand, the fact that the momentum of a moving vehicle remains “Earth-normal,” its traction is greatly reduced in the Moon’s light 1/6th normal gravity, means that extra attention must be paid to banking on curves and/or providing surfaces with enhanced “grip.”

The earliest frontier roads; marked trails

Getting down to the nitty gritty bare bones essentials, a road or trail is essentially a route that someone has pioneered and which is visibly evident to anyone who would follow or retrace it. On the Moon, footprints and wheel tracks in the soft, easily compacted moondust, will remain visible for centuries or more.

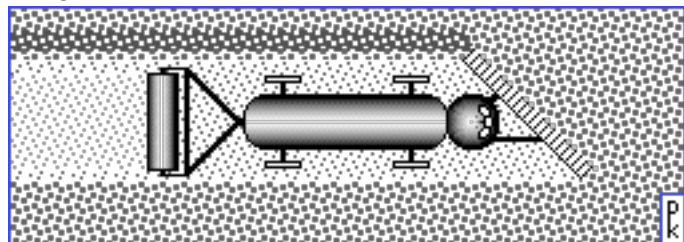
The amount of effort to be made in “constructing” a “road” depends on the amount of “traffic” that we anticipate. Clearly, that will change with time. In our own experience, ungraded dirt roads give way to graded ones, then gravel, and finally paved byways.

The first outpost may have a number of frequently visited outstations: out-vac tank farms of fuel and other volatiles; warehouses; remote nuclear power station; a launch pad in early stages of becoming a spaceport; a scenic overlook or two; areas of enriched raw materials for early industry, etc. And there will be exploration and prospecting sorties to areas further afield, possibly scouting sites for additional outposts or “industrial parks.”

To aid in route surveying and “highroute” corridor designation, we will need more accurate, higher resolution lunar global altimetry maps than those now available. Based on the maps yielded by such a TopoSat, potential corridors and routes of varying breadth, both main and tributary branch routes, can be identified prior to decisions on where to site new outposts. Proximity to such routes linking potential sites to the early population centers will be a primary, if not overriding consideration in final site selections. This map of potential traffic routes, color-coded for sections needing special improvement, identifying and quantifying clear-grade and cut-fill hurdles according to difficulty and expensed options will provide one part of a Global Lunar Development Map.

Given the Moon’s low gravity, grades steep by our own terrestrial standards, may present no big problem, at least not for wide-track vehicles with low center of gravity. But we’ll want to pick paths with gradual changes in grade, and relatively free of large boulders – routes that promise to be relatively easy to negotiate – and which do not lead to dead-ends, e.g. into a box canyon, toward a cliff or escarpment, or into jumbled, chaotic terrain.

The simple passage of other vehicles following a first trail, will compact the moondust, making the route more clearly visible and easier to follow. But without minimal improvements, average speeds may be rather low. In general, routes will be picked that steer clear of boulders of any size, say a foot (30 cm) or so high. These smaller ones can be handled by the vehicle’s suspension but wheeling over them will make for slow going. It will make sense to provide vehicles with a forward, canted rake that will “plow” them to one side. A second parallel pass would widen the “smoothway” to two “lanes.” If the “plowing” vehicle has a trailing weighted roller, then smaller rocks of a couple inches (5 cm) or less will be compacted along with the moondust, making a rut-free smoothway that can be driven at modest speeds. With no additions of extraneous material, the road’s color will be that of the host terrain, blending in perfectly. It will show up, from close up or far away, mainly by its clearly “processed texture.” The earliest “roadmaking,” then, will be a matter of “Rake & Roll.”



Trail Smoother rakes/plows small rocks and boulders to one side, leaving pebble size rocks behind, to be packed into soft regolith by the weighted trailing roller. A row of boulders is left to one side. A return pass by the

Smoother on the far side of the boulder row, will thicken that row and create a median strip. Boulders in the median strip can be removed where needed to allow left turns onto junction roads. Additional reverse direction passes to either side of the median would widen the smoothway, and create smaller boulder rows marking the two shoulders. How wide and high would the boulder rows be? That would depend on the amount of boulders in the area smoothed. The boulder rows may be discontinuous, but would still effectively mark the way.

[For a way to trailblaze pioneer roads at no public expense, see Luna City Yellow Pages, this issue, page 8, # Trail Blazers, LLC.]

“Fixing” the roadway: dust-control

Away from settled areas, dust control, while always helpful (reducing and simplifying vehicle maintenance) will be less important. Depending upon traffic volume, the simple clearing of boulders and modest “smoothing” may suffice over carefully surveyed routes. But regularly used traffic ways need be more than rut-resistant. They should also be dust-free or dust-stabilized.

Surfaces can be self-paved by fusing or sintering the top layers to a sufficient depth to support expected wheel weights, using microwave beams in a stereo array or focused solar beams in a controlled pattern to produce a hard but not glassy surface, textured to improve traction of spring-tired vehicles. Just how to do this is a matter that will require some amount of determined experimentation, first Earthside with analog materials, then with infield/ onsite confirmation tests with actual lunar produced materials under real travel conditions. Determining cheap and easy pavement options should be a priority “homework” item for the initial outpost-base.

One challenge will be the high surface temperature range of +400° F, +200° C., over the month-long dayspan-nightspace cycle. This will constrain the way and extent to which potential dust-fixers like sulfur are used. “Pavement” strengtheners such as locally produced fiberglass mats may be part of the solution.

As to lunar concrete bear, in mind that this is a sixthweight environment and the “pavement” need not be as strong as that needed to bear up under heavy terrestrial traffic. At the same time, on the early frontier, we can expect a large percent of the traffic to be that of heavy “lith-moving, construction and mining equipment. On Earth, a six to one mix of raw on site soil with cement is enough to produce a serviceable walkway. But will such a low ratio mix sustain construction equipment traffic as well as lighter road traffic? Tests are needed!

Right of Ways and Road/Lane Widths

How wide should a rural highway be? This may seem a strange question. But on the wide open owned-by-nobody Moon, there would seem no reason to arbitrarily limit the width of vehicles, and determine lane widths accordingly.

There are no potentially productive lands being eaten up by wider highway rights-of-way. With no air or atmosphere, there is no need for streamlining either. (“dustlining” is another question!) There are as yet no bridges or underpasses or tunnels of set size to influence width and height restrictions. On the other hand, there is low gravity – which brings with it proportionately low traction – along with unreduced full-normal momentum. Together, these conditions make wider than normal track and lower than normal center of gravity, wise design goals. We predict that lunar highways may be generously wide, lane for lane, by our standards.

But roads can always be widened, if the right of way set-aside is appropriately generous. At the very outset, where the traveler does not expect to meet oncoming traffic, one ample lane should be enough. Two ample lanes with a rock median strip, as described above, should do for quite some time. Eventually populations in various centers, and the trade and passenger traffic between them, may make wider, and even “limited-access” roads advisable.

Graded trails

The simple roadway preparation above, may work well enough for relatively flat mare [pronounce “MAH-ray”] plains of the Moon, the so called seas (actually seas of great lava sheets now long congealed), their upper surfaces reduced to powder and rubble by billions of years of meteorite bombardment and micro meteorite rain – the patchy areas of the Moon that look dark gray to the naked eye. And it is our guess that the first major lunar settlement will be built near a mare/highland coast, proba-

bly on the mare itself, for the significant industrial advantage of having access to both aluminum–calcium rich highland soils, and iron–titanium rich mare soils.

But even the maria (plural of mare, Latin for sea, pronounce MAH–ree–ah) are not totally smooth. Successive lava flows have left terminal slopes. Here and there, lavatubes too close to the surface, have collapsed into valleys called rilles, hundreds of meters wide and deep, many kilometers long. Here and there also, more recent major asteroid impacts have cratered the mare surfaces.

And in some major impact basins, Mare Smythii being a good example, the subsequent lava floods have been too shallow to bury the older heavily cratered impact basin. The rims of ghost craters poke through the mare surface like so many coral atoll reefs.

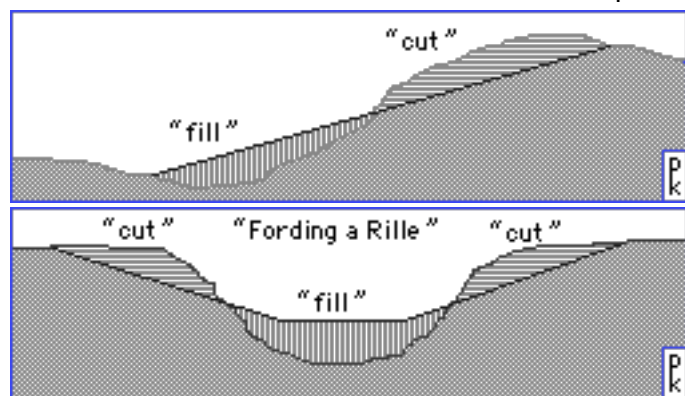


Lighter, crater–pocked highlands surround darker and flatter lava flood plains called maria. The mare, in turn, has several deep rille valleys (left) and flow front escarpments (top) as well as a few younger craters. And in the highlands, even where reasonably negotiable routes can be found through “inter–crater plains,” road making may require more than boulder plow–raking and “smoothing.” Ag–gressive grading may be needed to fashion lanes free enough of small scale dips and mounds to permit acceptable travel speeds. What our Trail Smoother begins, or cannot even touch, will be the job of bulldozers, graders, and other earth moving equipment.

It will be some time before roads outside the peripheries of the settlements are used regularly enough to constitute what we would call “traffic.” Only when they do, will substantial grading, paving, and routing improvements to allow higher speeds and shorter trip times become financially justifiable budget priorities.

Forging shortcuts: cut & fill, causeways, bridges, tunnels

These early paths–of–least–resistance routes will do well enough for a start. But as global lunar population and inter–settlement traffic grows, ‘shortcuts’ demanding extensive “cut and fill” work, perhaps even bridges and tunnels, will become justifiable expenditures. Looking at the sketch above, it is clear that without such engineering, we may have no choice but roundabout routes, sometimes a hundred miles or more longer than a direct route. That means more hours spent in transit.



It may be some time before bridges and tunnels are built. “Cut & Fill” is easier, less expensive, low–tech: ideal for a small population with limited industry. The lunar surface is bulldozable down to a depth of 2–5 meters, 6–16 feet. Below that lies fractured bedrock. So major “cuts” will need the assistance of dynamite or other explosives.

Scenic Highroutes

On Earth, “scenic” roads often hug terrain features such as valleys, shorelines, ridges and mountain crests. On the Moon, it will be no different. Routes chosen for the views they afford will wind along rille tops or bottoms, crater rims, and mare coastal ramparts, lava flow fronts etc. As they may well be

more expensive to build, such roads will come later, multiplying step by step as the domestic and foreign (terrestrial) tourist traffic increases.

Automated Self-Serve Roadside Service Pods

For travel off the beaten path, we must use self-contained vehicles that need no resupply other than what is obtainable from the surroundings. Range will be limited. But along improved roads open to routine travel, wherever the distances between settlements and outposts are substantial, safety and convenience will be promoted by the placement of automated solar-powered service stations.

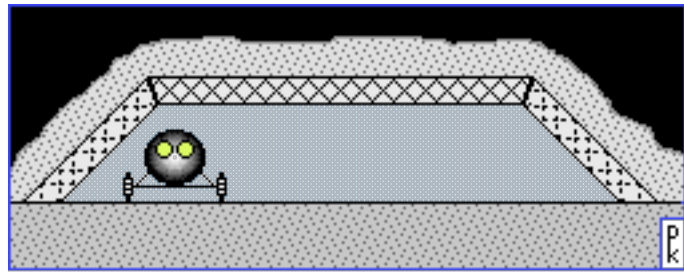
At such "pit-stops," vehicles can pull up and hook up to refuel or recharge. The station's solar power units will recharge exhausted batteries, electrolyze water from fuel cell operation to make hydrogen and oxygen for refueling other fuel cells. And there will be on site solar power storage for limited nightspan operation.

First aid supplies may complement emergency food rations. An antenna for high gain communications is likely to be available. There may be a locked storeroom stocked with commonly needed parts and tools, accessible by credit card. Use a tool and don't return it, and you get charged not only the purchase cost of the item, but the cost of restocking it to the location at which it was "checked out."

A computer in the main town could keep track of vended inventories and the quantities of water, hydrogen, oxygen, stored power reserves etc. This will allow scheduled just-in-time resupply and equipment maintenance. Such Stations can be designed as compact units with modular pull-out/plug-in changeable components. They would be trucked to the site, following road-blazing crews, or in advance by all-terrain scout vehicles.

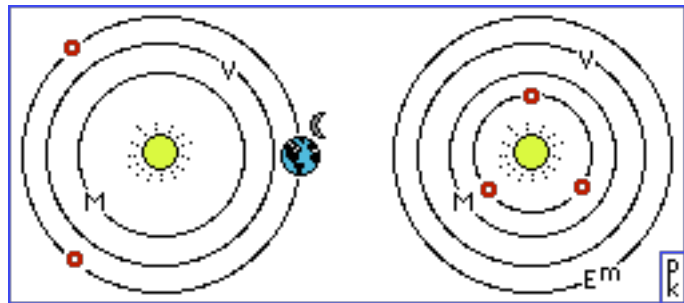
Next in priority will be "flare sheds," covered hangers where vehicles can find shelter from the occasional solar flare. Those readers who had the luck to see the made-for-TV Disney-ABC science fiction film

"Plymouth" (shown only twice, Memorial Day Weekend in 1991 and '92) will appreciate the importance of such sanctuaries from the powerful radiation of solar flares.



As advance warning time for solar flares is rather minimal, these havens need to be placed at "reachable" intervals along regularly traveled routes. It will be a high priority for the safety of lunar pioneers to agitate for early placement of flare-warning stations in orbit around the Sun.

A minimum of two 120° ahead and behind the Earth-Moon system in the Earth's orbit around the Sun will do. Three, at 120° intervals in a close-in, within the orbit of Mercury, might be better. These orbiting satellites will be able to see around the flanks of the Sun to spot troublesome sunspots before they are carried by the Sun's position to the field of view visible from Earth or the Moon.



LEFT: A 2 satellite system in Earth orbit covers parts of Sun out-of-view of Earth & Moon to give complete advance warning. **RIGHT:** three satellites cover the solar globe at higher resolution, from an orbit inside Mercury. at higher resolution, from an orbit inside Mercury.

A complete network would monitor developing storms anywhere on the Sun's surface. With such advanced warning, flare sheds could be placed at greater intervals. Such sheds can be designed and erected in modular fashion, to grow in shelter capacity as road traffic warrants. In time, some of these refuges may become the nuclei of staffed service centers, including restaurants, lodging, and even recreational facilities.

Motoring on the Moon will be a very different experience for those accustomed to road travel on Earth. Here, even in remote areas from from the roadside spam of non-point-of-interest billboards, even in the most arid of desert and mountain areas free of vegetation, we enjoy conditions not to be found on the Moon. Without water vapor laden air, lunar skies will be black, even when the glare of sunlit moonscapes is intense. A passing truck will be scarcely noticed, with no telltale "suction" effect as it passes. Vehicles will have to be fully pressurized and more dependable, with backup systems. Without air and wind, awnings against the solar glare will cause no drag.

Properly routed, with scenic overlooks and opportunistically placed waysides (replete with sculpture gardens) lunar highways need not be boring. Yet, to the same people who on Earth feel that "when you've seen one mountain (river/waterfall/lake/cliff/valley) you've seen them all" the Moon will be especially boring. To those of us capable of sensing and appreciating the differences and who marvel and are awestruck by the endless variety, there will be no shortage of scenes full of wonder.

Early highway passenger vehicles will be more akin to our "coaches" or "greyhounds", not in shape or size, but in function. Personal and private vehicles will be available on pressurized in-settlement streets, long before they become affordable or common out on the surface. When they are built, they may be mainly rental vehicles. Few pioneers will need personal transportation between settlements until the population grows substantially, and the economy has diversified considerably.

<MMM>

Relevant articles from these past issues of MMM

37 JUL '90, "Flare Sheds" pp. 4-5

79 OCT '94

p 13. Lunar Roads

p 16. Lunar Vehicle Design Constraints

81 DEC '94

p 3 Rural Luna: Surface Vehicles & Transportation

p 4. Over the Road Long Distance Trucking Rigs

p 5. Toadmobile Conversions

p 6. Beyond the Beaten Path: Skimmers

p 7. Spider (vehicles); Camping Under the Stars

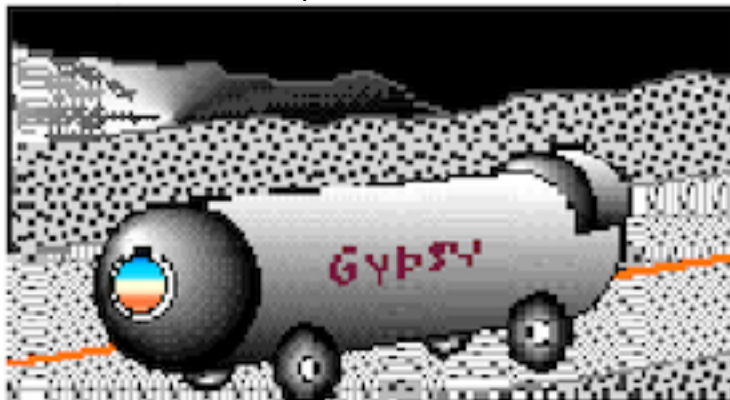
82 FEB '95 p 7. Rural Luna: The Beaten Path

85 May '95 p 7. Waysides; Farms; p 8. Mines

86 June '95, p 7. Science outposts; Recluse outposts

Pursuing Nomadic Lifestyles on the Lunar Frontier

By Peter Kokh



We've talked a lot about lunar homesteads and lunar settlements in the past seventeen years of MMM. And indeed, the goal of most pioneers who leave Earth for the Moon and wherever else, will be to

settle down in a place that they can call home for a long time, if not indefinitely. Yet we know from our own experience here on Earth that not everyone ends up in a home of their own.

Many persons prefer not to set down serious roots, even after establishing a family, choosing to rent here and there as fits their mood or changing job situations or finances. Surely there will be home rental and apartment type living on the Moon and elsewhere. But in this essay, we want to speak to a less common need, but one which will certainly be part of settlement life for some.

There are people whose jobs or occupations by their very nature requires a highly mobile, sometimes even nomadic lifestyle. One example is the expert whose rare talent is needed now here, now there. He or she may be a mining consultant, an architect, a corporate organizer -- you get the idea. We are not talking about people who are here one week, there the next, but those whose services may be needed here one year, there for the next six months, and so on. They will hardly be happy living out of hotel rooms, never sleeping in a bed of their own. Yes, what we now call "residence hotels" will be an option: quarters that you can settle into, somewhat, with some leeway in superficial customizing being allowed. Perhaps that solution may do well for most of these mobile persons.

But some may want to have their own homes and a permanent home to come home to between stints won't do. They want real homes that they can take them along with them as they move around to wherever business and life takes them. Yes, some analog of what we call mobile homes, motor homes, houseboats, etc. That is the life style we want to explore on the Moon, and those are the analog solutions such people have found workable on Earth.

Various Mobile Habitat Analogs

We are familiar with various types of mobile habitation. Most mobile is today's motorhome, able to go anywhere there are roads, fully self-contained, on wheels with its own engine. Less mobile are trailered and "5th wheel" homes and campers. Next there is a category which has undergone major evolution over the years: the old pick-up-and-go "house trailer" ("caravan") was replaced with the "mobile home" that generally made but one journey, from factory to a fairly permanent "trailer park" site. This has evolved further into manufactured modular housing.

We'll certainly see a lot of the later on the Moon and Mars. In fact, we think manufactured modular housing will be overwhelmingly predominant. It ensures quality and safety performance, minimizes the amount of time spent by workers in space suits, and is best adapted to meet the needs of a quickly expanding population.

But it is the previously mentioned mobile habitats that are in the range of our topic, and we'll probably see analogs of all of them on the space frontier, along with one other, the house boat and the bargeable floating home. There will be such a variety for two basic reasons: to fit different situations such as expected frequency of relocation, from constant to seasonal to seldom; they need to fit the life-style needs and quality expectations of people with different tastes and budgets.

On Earth, many of the larger motorhomes keep personal, smaller, more maneuverable vehicles in tow, much as their waterborne equivalents are equipped with dinghies. We'll probably see something similar on the Moon, but in two basic forms: a small electric cart (think golf cart) for use in pressurized piers and likely-adjacent settlement passages; a fully pressurized out-vac rover. For scarcely mobile lunar habitats on the analogy of floating homes (Seattle's Lake Union, Sausalito) there will be contractors to move them to new sites for a fee.

Mobility Constraints

On Earth, such movable residences must meet certain design constraints to fit the medium in which they are mobile: motor/trailer homes can only be so wide to avoid "wide-load" restraints and only so tall to slip under most bridges; houseboats, bargeboats and floating homes can be limited to where they are able to (re)locate by canal widths, lock widths, fixed bridge heights, etc. Will analogous, if more generous, constraints affect mobile homestead design on the Moon? If there standard clearance height is adopted for roadside solar flare shed shelters, and for "service station garage repair bays" these standards will tend to limit height / width. Road overpass clearances may be in line with those of flare sheds and service bays.

Mobile lunar residences will be built in all sizes, as they are on Earth -- from minivan to Greyhound Bus conversions. Customer families will come in all sizes and incomes.

Marina, RV Campground Analogs

On Earth, movable residences are self-sufficient, to a point, but for long-term use need specially equipped parking or docking spaces with utility hookups as a complement. What will the lunar analog of

an RV campground, a trailer park, or a houseboat marina be like? Marina/'RV parks may impose set size limits, chosen to cater to most common vehicles.

Common Marina Services include: general store (groceries, miscellaneous parts and supplies); utility hookups (electricity, water, waste treatment & CELSS regeneration, cable-vision); mailboxes & general delivery, fuels, commons complex (recreational/social activities); transit interface.

Deluxe marinas could offer much more. Attached to the docking portal could be additional enclosed "elbow room" space for the usage of one's choice -- for rent or lease, of course. Assuming that the dock portals all open on a pressurized pier or lane, a deck-porch area for socializing with passersby could be included. Taxi service could be provided for larger units that cannot dock directly but park at some distance at outlying utility hookup spots.

One particular service will be in high demand. A habitat may be designed to perform primary treatment of human waste water (before the effluent passes into settlement systems). It will be impractical for a mobile habitat to provide complete treatment. The marina could accept pretreated waste water in exchange for fresh water as a standard utility service. The marina would also maintain a list of reputable local contractors to meet all the servicing needs of their guests from CELSS systems to power and communications systems and more.

Such marinas could be designed and assembled in modular fashion so that they can grow with demand. To serve as movable "construction camps" a bare bones dock and pier complex could be designed of inflatable elements to be erected in the shelter of a shielded hanger / ramada.

These would be especially useful for construction sites sufficiently remote from the main settlement(s) as to make worker commuting difficult.

Shielding: tortoise or hermit crab?

For any kind of frequently roving or infrequently relocated lunar frontier habitat, the question of shielding arises. On Earth our all-blanketing atmosphere provides protection from cosmic rays, solar flares, and micro-meteorites. On the Moon, we'll need a blanket of regolith or its equivalent in shielding protection.

For infrequently moved habitats, more on the analogy of mobile or floating homes, regolith shielding in place seems the logical choice. If sandbagged, this blanket could be easily removed if the need to relocate arises. For mobile habitats regularly or seasonally on the go, the hermit crab has a suggestion: borrow your shielding. Marinas can provide expansive full-shielded hangers for protecting all the vehicles docked at its pressurized piers.

But what can we provide for those who want to park in the out-vac wilds, far from any kind of marina or RV camp ground type facility? Presumably, they will carry a healthy reserve of water, complete with water recycling systems. While on the road, reserve water can be kept in tanks in the floor of the vehicle, to minimize the height of the center of gravity so as to maximize stability. When parked, both reserve potable water and reserve water in process of treatment, could be pumped to roof and side-mount tanks to intercept incoming radiation. A thin sheet of metal held in place 6" or 15 cm out from the tanks would safely intercept most micro-meteorites that could puncture the tanks. Interior baffles and automatic sphincters would minimize losses should a rare breach occur.

An alternative, for those who expect to camp in one spot for a week or so, would be a portable ramada or hanger. A folding fiberglass fabric over glass-composite or aluminum tubing framework could travel rolled up like an awning, be automatically deployed on reaching a parking site, and covered with blown on regolith with a remotely steered and operated "blower." The trick is to design such a gizmo so that the shielding regolith can easily be dumped or shaken off when its time to break camp, We welcome reader designs. Send yours to kokhmmm@aol.com!

Road culture & the gypsy, vagabond, nomadic spirit

Here at home, there have arisen a whole suite of subcultures among those who RV/camp frequently, among over-the-road truckers, among those who live in mobile home parks, among those whose occupation has them always on the move, and among those who are nomadic by cultural descent such as gypsies. In the early days of the lunar frontier, when population is small, there may not be a critical mass of like-situated persons-on-the-move to support development of subcultures. But as population grows, we're sure to see some of this.

Such subcultures may have their own music and song genres, their own figures of SEP, characteristic pronunciations, special terms and jargon, their own myths and collections of proverbs, and even in some cases, favored fashion and furnishing styles. It is even possible that these people-on-the-go

will become a distinct political constituency. And why not have a legislative representative—at-large to address their concerns?

Cultural diversity and a wide selection of lifestyle choices. Only a small percentage of settlers will adopt mobile living patterns, but their contribution to a healthy, high morale settlement population will be high. <MMM>

[As a boy in the late 40s and early 50s, the author dreamt of owning a “house trailer,” and in 1969 bought a used 8x35 trailer of ‘55 vintage and plunked it down on a rural plot in Northern Wisconsin where it has served as his country getaway for some 34 years now. Conventional construction addition of an extra bedroom and separate dining area were added 6 years later.

In 2003, thanks to a fellow retiree travel companion and his 22 foot Winnebago Rialta, he has gotten to experience “RVing” and RV Park life. He also has had a lifelong fascination with houseboats, and recently visited the major houseboat community in Lake Union in the heart of Seattle. He also has some limited familiarity with cabin sailboats and boating marinas.] ###

MMM #172 – February 2004

Using “Marsten Matting” to build Frontier Roads on Moon & Mars WWII Instant Runway Technology to the Rescue?

By Peter Kokh

Recently (January 25, ‘04), in cable TV channel hopping, I chanced upon a History Channel “Mail Call” episode that described an ingenious World War II technology used to provide stabilized runways on the quick in newly conquered territory. Bulldozing and grading are the first steps, of course, but these measures alone did not guarantee runways that could stand up, without rutting, multiple landings of heavier aircraft.

To the rescue, a soil-stabilization technology using open-grid matting invented in Marsten, North Dakota, hence the name “Marsten Matting.” You won’t find a dedicated article on this on the web, though there are hundreds of references to it. So our source remains what we saw in the History Channel episode.

“Marsten Matting” in its first iteration, consisted of open grid steel panels on the order of a foot and a half wide and 12–15 feet long. They interlocked to provide a continuous mat that could be beat into the loose soil, so as to support landing aircraft and aircraft taking off. Eventually, long runs of such matting would arrive on scene, pre-interlocked and folded, so that it could be just pulled off a flat bed of a truck and put into place, instead of each panel being carried by a pair of GI’s. The design of the mats changed over time, becoming ever more strong and stable. Lighter Aluminum mats, were tried also.

Sorry, but we have no pictures to offer you. Our best advice is to try to catch a rerun of that “Mail Call” episode. But if you do find a website with more information, please let us know at kokhmmm@aol.com.

Translating Marsten Matting technology to the Moon & Mars In our recent article on the construction of early lunar roads, MMM #169 , OCT ‘03, we described a vehicle which in one operation would shove aside surface boulders, and grade the soil, then compact it with a trailing weighted roller. The compacted surface could be further stabilized by microwave fusion of the surface powder. This might be enough to support light vehicles and light traffic. But it would seem prudent to construct lunar roads to be able to handle heavy equipment traffic from the outset. Paving them with “lunacrete” – lunar regolith with added made on Luna Portland cement – presupposes an industrial ability to make that additive in quantity. And the operation of paving roads in this way could be time consuming. Could there be an easier way?

Perhaps the use of “Marsten Matting” open-grid panels made locally on the Moon, along with microwave sintering of the regolith fines filling the grid openings, would do the job. A lot would depend on how the grid was designed and the materials of which it was made. What are the options – realistic options for an early frontier outpost wanna-be-settlement – options appropriate to an early frontier not so diversified industry?

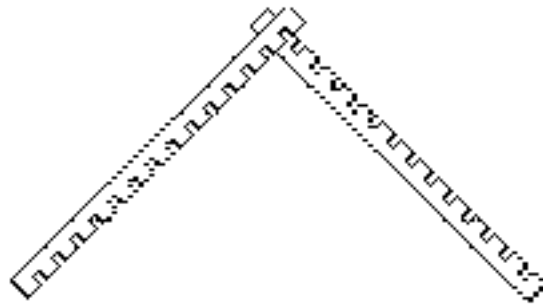
Steel seems desirable, at first blush, but a plant to make steel out of the iron fines in the regolith would seem to be a very ambitious undertaking for a small outpost. You'll want to first produce iron-enriched or beneficiated soil, then extract the iron, add the needed alloying ingredients, then pour the molten steel into the needed molds, then combine them into the desired mats.

We can make objects out of iron more simply, just by sintering free iron fines, small particles extracted from the regolith with a magnet and then sifted. But while "powdered metal" technology is good enough for some "low performance" items, this method could only produce brittle and friable mats that would disintegrate under the passage of the first vehicle.

Aluminum? The plant and equipment necessary to produce aluminum would also be prohibitively extensive and expensive for an early outpost. Magnesium or Titanium? As with aluminum and steel, we'd have to have the prior capacity to extract and isolate the needed alloy ingredients.

Glass would seem to be an unlikely candidate. But mid-eighties experiments by Goldsworthy-Alcoa funded by grants from Space Studies Institute, showed that glass fibers, made from crude lunar highlands regolith (with a relatively high melting point) and embedded in a glass matrix made from crude mare regolith (with a relatively lower melting point, lowered further still with a lead dopant brought from Earth) would produce a hardy composite with "twice the strength" of common steel. (Our advice has been to forget about imported lead as a dopant and to use readily producible lunar sodium and phosphorous which would lower the matrix melting point almost as much.)

A follow-on SSI study showed that a highly automated plant to produce glass composites on the Moon need weigh only a few tons, making it ripe for a lunar startup industry. Open grid mats could be designed tailor made for the fabrication methods that prove most workable for lunar glass-glass composites. Square mats of crisscrossed interlocking identical spars would require only one mold and an easily automated assembly process.



Larger glass-glass composite grids of similar design could be used to stabilize steep shielding berms. <MMM>



Blacklight Fantasy Excursions

By Peter Kokh

In the previous article, we spoke of blacklight-lit fantasy out-vac surface gardens on the Moon's Farside where truly dark nightspan conditions exist. Yet despite the glaring presence of the Earth in the Nearside nightspan skies, there is opportunity galore for this kind of fantasy lit fantasy gardening on Nearside as well, within lavatubes open for public excursions and tours. It is not impossible that without the addition of anything artificial or human-altered, just with blacklight, lavatube surfaces may include spots and streaks that shine brilliantly in blacklight. We won't know that until we go there.

We can test if that is the case in terrestrial lava tubes. Our friends in Oregon L5 who have spent so many hours in a pair of lavatubes outside Bend, Oregon may have already thought of this and tried it. In the summer of 1992, with Oregon Moonbase team members Bryce Walden and Cheryl York as my hosts and guides, I had the chance to explore these tubes, much to my delight and fascination. I was amazed by the diversity of texture in the walls and ceilings of the tubes, testimony to the varying temperatures and viscosities of the flowing hot lava that formed them thousands of years ago. It had not occurred to me to bring along a black-light flashlight.

Preparing preexplored Lavatubes for Blacklight Excursions If the surfaces of lunar lavatubes prove to be sensitive to blacklight, a host of practical questions remain before installation of a blacklight system can become a technically and financially feasible project. The tubes are vast in size and a lot of power, lamps, and wiring would be needed. For "dayspan-only" tours, power could come from solar collectors on the surface. This site could be operated by a commercial concession in a prime tourist traffic area.

We are talking about an era well into the future when there will be a substantial resident population and industrial infrastructure in place and when tourist excursions from Earth are popular and affordable. But even if none of us live to see that day, the possibilities can excite us and motivate us.

The blacklit lavatube could include fantasy forests and sculptures, all glowingly and beautifully revealed by blacklight. There are no limits, and like many tourist facilities, the manmade features of this site would likely grow as profits from tourists were plowed back into the investment.

Why not an Earthside enterprise analog? </MMM>

<http://mywebpages.comcast.net/jtozour/links/links.html>

NOTE: for more on fluorescence in rocks, visit: Tozour Family's Fluorescent Rocks Links and Updates Page

MMM #175 – May 2004

Creating "Nature Walks" on the Moon

By Peter Kokh

Perhaps most of us have been somewhere in the countryside, mountains, forest, desert, shoreline, and have noticed a sign "Nature Trail" and decided to take the plunge. Chances are we will have enjoyed it, and if we took the time to read all the signs attempting to inform us about what we were looking at, emerged with a bit deeper insight into nature's wonders and mysteries.

Some Nature Trails may point out a few geological features such as rock outcrops, waterfalls, and so on. But by and large, most of our Nature Trail educational tidbits are about flora (plants) and fauna (animals.) We tend to take the host geological setting for granted. And precisely because there seems to be a so much greater wealth of detail to wonder about and to delight in when it comes to plants and animals, the subtle differences in texture and color of rock and soil are at best, enjoyed as is, with no felt need to learn names, classifications, or significances. We simply take the inanimate context for granted.

I think on the Moon it will be different. Yes, we will have flora and fauna nature trails, but inside human-created mini-biospheres. Out-vac, on the barren lifeless surface, Nature Trails through the "magnificent desolation" will have only geological items to highlight and educate us about.

We do have a primeval need to identify salient things and details in our environment. It is the Adamic urge to "name" things. In the absence of visually distinctive plants and flowers and birds and other creatures to identify and "tag" with a name, I think our attention will automatically shift to subtle differences in the inanimate setting that we would not have paid attention to if plants and animals were present. Nature abhors a vacuum, goes the old saying, and so does the mind. The way this rock is shaped and textured and colored differently from that one will take on new significance and importance, in the absence of other things upon which to focus.

An Analog Moon Nature Trail Experience

This was all brought home to me most vividly in the summer of 1992, when, as the guest of Bryce Walden and Cheryl York of the Oregon L5 Society, I had a walk (and at one point, crawl) through a tour of the pair of lavatubes that, at that time, constituted the "Oregon Moonbase" just outside Bend, Oregon. Being rather familiar with limestone caves full of interesting stalactites and stalagmites and other water-flow and drip-created features, I had expected a tube created by flowing lava to be rather uniformly devoid of interest. But I was amazed to see how the texture of the lava-flow-formed walls varied from place to place. I counted at least eight distinctive surface types. I felt the need to be able to identify this texture from that one and to understand what caused the differences. These details are things I may perhaps have noted, but paid no more attention to in a setting with plants and/or animals in the foreground to hog my attention. And there we have it. Geology for most of us remains in the

background, because the living foreground pops out and monopolizes our awareness. Absent life, geology is the foreground and zooms into focus.

On the Moon

When we look at Apollo Moon mission footage, we notice differences, but perhaps do not dwell on them. The scene seems desolate and monotonous. Hello! There are no plants and animals – things we are used to seeing most everywhere on Earth. But for the Lunar pioneer, once the ingrained expectation of living entities no longer fogs our interpretation of what we see before us, I think we will start noticing this and that about the moonscapes – the subtle yet somehow interesting differences between this view and that, between this location and that. In the absence of other things to “recognize” by name, we will want to know the name of this feature or that, and in the absence of that information, start creating names from scratch.

A lunar settlement will soon create nature trails through areas in which there are a variety of features that are noticeable, and about which the history of their formation, the mineralogical, and potential economic importance will be of interest (again, lacking anything else – read: living – to focus upon).

With the best of attitudes towards the Moon, most of us, given the chance to take a coach tour on the Moon, will become a bit bored after a few hours or miles. We don't appreciate the distinctions in what we are seeing. Consider these parallels on Earth. In the absence of the cultivated ability to see and appreciate differences, “when you've seen one waterfall, mountain, or city you've seen them all.” Boredom is not without guilt. It comes from failure to cultivate an appreciation of distinctions and differences.

In the near and not to distant future

Nature trail education will help Lunar pioneers and visitors to enjoy what they see more thoroughly. But why wait? In the very near future, any of us will be able to go to the nearest IMAX theater and enjoy as never before possible, in wraparound attention-captivating detail, the moonscapes actually photographed by the Apollo astronauts, thanks to Tom Hanks and his crew and Lockheed-Martin. Look for “Magnificent Desolation” to open soon, and go see it again and again. See MMM #174, APR '4, p. 12

And why not fly a photographic lander-rover to an interesting spot on the Moon, do a lot of videotaping, and have Moon geology experts edit the footage for the more interesting and significant items, and with the help of science popularizers, create a DVD or IMAX Nature Tour of this or that moonscape we can all enjoy while stuck here on Earth. In the process we will be learning to appreciate the subtleties, and find the Moon a much more interesting and intriguing place. <MMM>

MMM #176 – June 2004

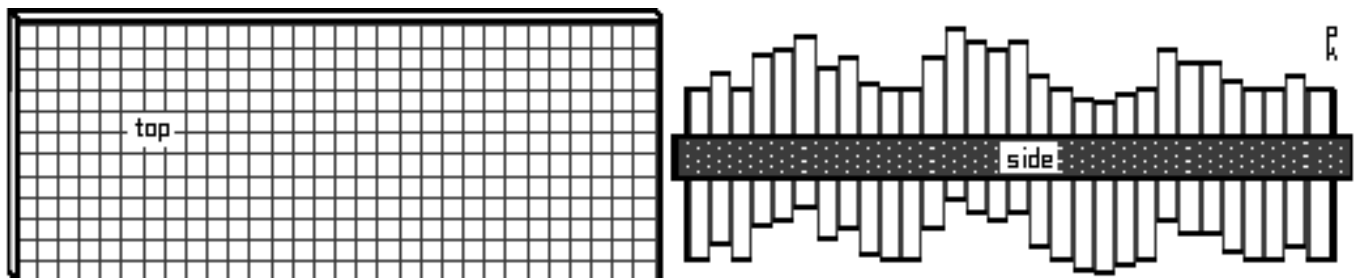
Tele-Crafted Art Objects

Creating Art on the Moon before the next humans arrive

The next step beyond Moon-relayed messages and advertisements could be tele-art. We are still in the realm of products delivered to Earth-bound customers electronically, no physical objects shipped. What more could teleoperable landers and lander rovers do or produce for telesales on Earth? As with video games, progression from the first pingpong games to today's multi-megabyte games played on high definition screens, the potential for progress from first humble offerings to sophisticated products is great. And what better prospectus could you have for a teleoperable space enterprise!

The idea is simple. The lander, or lander-rover is equipped to make things in, or out of, the regolith moon dust at its location, and relay photos of these creations back to Earth for the enjoyment of their telecreators, gift recipients, and others. What are the possibilities?

Drawing in the moon dust with a “stick” or wand: the moon dust is cohesive enough to hold crude shape. The crisp Apollo bootprints are ready proof of that. Getting beyond the stick, a stamper made of tele-extendible pixel rods or bars could stamp any sort of pattern/picture in the soil, dependent on its “resolution.”



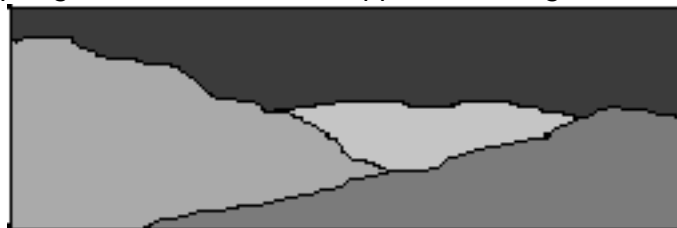
The ability to “fix” the stamping by microwave sintering would be an asset. People could order “moon bricks” (to remain on the Moon but with their photos relayed back to the person placing the order) with their own name or the name of a beloved or departed person. The stamping could be a hand-print or footprint or bootprint.

Or it could be a simple message. The apparent drawbacks of this idea are (at least) these three:

1. the scale would probably have to be large, if keeping with the degree of detail and resolution desired
2. the lander rover would have to keep on the move, as it would quickly run out of stampable terrain within reach\of its landing spot.
3. if microwave sintering is used to ensure “permanence” the power requirements of the rover would be greater

The next step beyond simple stamping would involve altering the moon dust to tele-create art objects and sculptures out of crude moonglass and ceramics. Once we get beyond simple microwave sintering, the power demands go up along with the temperatures involved. Iron fines gathered by a magnet, could be shaped and sintered (powdered metal technology) into objects of art. Glass making would be more ambitious. A solar concentrator mirror could supply the high temperature needed. Designing tele-shapable mold apparatus would be the trick. But perhaps someone out there is up to the challenge.

Quite another idea is to sift the moon dust and then run it through an apparatus capable of sorting the particles for shade and color. A tele-artist on Earth could draw on the bin sorts to create “sand paintings” in twin-paned glass frames open at the top, and webcast to Earth. If these could be preserved somehow, they could be traded on some sort of Art Futures market, against the day further into the future, when they might be retrieved and shipped to the high bidder on Earth.



The same sort of thing could be done with glass spherules sorted from the moon dust, and again sorted for color. The visual effect and texture of the “painting” would be different and richer. The coarser rock and aggregate bits removed by the sifting process, could always be added back in, sparingly and deliberately placed for the desired accent. Preservation of such art objects could be by microwave sintering. The big trick is to supply, or make, a suitable durable substrate for these fragile creations.

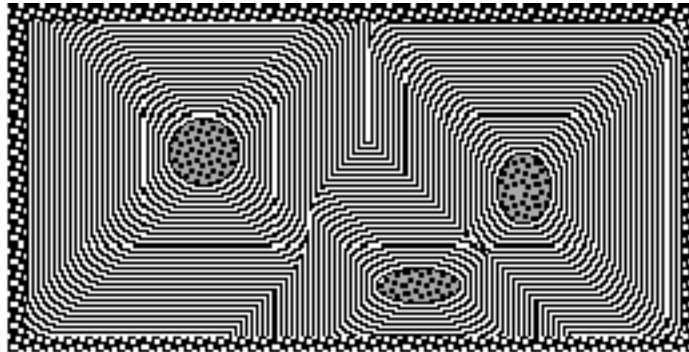
Glass and iron-fine jewelry and coins have been suggested, but again, these ideas are for the next round, when shipment back to Earth is possible and affordable. We are more concerned with objects of art that can be telecreated on the Moon, and enjoyed long-distance via the web or relayed photos, auctioned off in an Art Futures market against the day when they might be retrieved, or become part of a sculpture garden for future Lunans to enjoy.

A more ambitious idea would require a rover with a manipulator arm that could pick up tele-selected rocks or breccia aggregates and pile them up into interesting sculptures. Without some sort of glue or binder, however, this possibility seem limited to gravity-shaped piles. In that case, the art would be in the choice of rocks and the overall visual “texture.” On a grander scale, a sculpture on Earth could create a lunar Stonehenge of sorts. A lunar Stonehenge could even be designed to showcase astronomical events. An installation of this sort along the 90° E or W longitudes, in the middle of the limbs, could be designed to show maximum elevation of Earth above the horizon, i.e. librational extremes. How long

it takes for the teleoperated device to create any such grand object is immaterial, if the device is solar-powered. All that is of concern is that the device be strong enough to handle the largest sculpture component that needs to be moved, as opposed to being left in place.

Primitive prehistoric stone works could serve as inspiration. Such larger scale art projects would endure indefinitely, to the delight of the eventual pioneers. And for them too, such rock works would be “prehistoric,” tele-made on the Moon before the arrival of first settlers. Perhaps this doesn’t conjure up anything of much interest to most readers. But then most of us do not have the unbridled imaginations of artists, and of an artist turned loose in a brand new medium!

Besides Stonehenge-inspired creations, artists on Earth could make serene Zen/Japanese rock gardens with well-selected and carefully placed rocks set in a pool of ripple-racked moondust, bordered by a row of smaller rocks.



Zen gardens can be created around any trio (the desired number) of nice boulders left in place, simply by raking the regolith around them, piling up the rake-removed smaller rocks in a row around the perimeter. That would remove the need to select and move the bigger rocks that are to be the garden’s focal points.

All the artistic creations accomplished through a given lander-rover-manipulator would remain in one general area. A sunset task for this teleoperated art machine might be to grade and tamp down, and possibly sinter, a “sculpture garden pathway.” Then the rover would make a final video tour complete with documentary script, with the original artists making the voice over commentary.

Such sculpture gardens would in time be visited by actual tourist visitors, from the settlements and from Old Earth itself. Such a park could be named after the lander-rover-sculptor (“Moonsculptor I”), or after the most award-honored individual creation in the park (e.g. **Moonhenge III Sculpture Garden**), or simply after a prominent nearby geographic feature (“**The Taurus-Littrow Prehistoric Sculpture Garden.**”) The finishing touch of working all these tele-creations in a Garden Park would help counter those who object that we are “defacing” the Moon.

Without the presence of weathering agents other than the light incessant micrometeorite “rain” that should take many of thousands of years to erode the Apollo bootprints, these creations will endure in their exposed setting for a very long time. The more highly-valued can always be relocated within some future settler museum.

Prospects for Tele-art on the Moon

We are not talking about art created by robots – robot art. Real human artists on Earth, their hands inside virtuality teleoperation gloves, would go through the motions of placing, shaping, working moondust and moon rocks into the object conceived in their heads. For first timers, this will be a learning experience and preconceived ideas of what they will be able to do may quickly go out the window as they learn hands on what they can and cannot do, both via teleoperation, and with actual moondust and rock. Some will get the hang of it faster than others. And some will produce objects of more widespread appeal than others.

Can we do the same thing on Mars?

There is less than a 3-second time delay in the execution of a teleoperated command on the Moon. For Mars the delay would range from 6 to 40 minutes. The long answer, however, is yes. One could create a teleoperation program and let the computer execute it, removing the artist from the time delay loop.

Outside of contracts for future delivery, money might come from friends of art sponsors and benefactors, or by sale of lottery tickets for the chance to tele-craft, to extend one’s artistic abilities

virtually to an alien material on an alien shore. A considerable fringe benefit may be from media exposure and publicity.

precedent of treating the moonscape with artful respect will strengthen the case for prior agreement on environmental protocols. The Moon has no biosphere to pollute, but that does not mean that it can't be visually "trashed." Tele-created art objects may lead to prior set-asides of geological and scenic preserves, and other guidelines that will guarantee the Moon remains beautiful for its future inhabitants. Meanwhile, the expectation that pioneers cannot be far behind, will spread. <MMM>

The Black Sky "Blues"

"BLACK SKY BLUES" Revisited

[cf. MMM #138, "The Black Sky Blues"]

By Peter Kokh

In the earlier article four years ago, I wrote:

"We've all grown up with the night. We don't mind it. Nighttime darkness is only temporary. With dawn comes welcome visual relief. On the Moon, that relief never comes. Our pioneers will be transplanting themselves to 'Black Sky Country.' And that can have long term psychological consequences.

"With the sky black even at 'high noon,' the contrast volume between surface and sky is intense. Shadows are bottomless visual pits. This will cause some eyestrain. Of course, this will be more of a problem for those who spend a lot of time out on the surface – in the 'out-vac.' But it will affect those who spend most of their time in pressurized spaces as well: in what they see through various types of 'windows' (visiscreen, periscopic windows, etc.); it may affect 'sky-lights' as well."

I suggested that spacesuit helmet visors might have a "differentially reflective coating that would 'brighten'" the sky, even if just a bit, without interfering with clarity of visibility of the moonscape." And that for skylights, perhaps we could "produce some sort of frosted and translucent, but not transparent, glass pane that will not only let in sunlight but appear itself to be bright, giving the illusion of a bright sky beyond."

"Without real experimentation, we would not pretend to guess what will work best.

But we should be trying a lot of things, including foamed glass, aerogel, special coatings or laminate layers, etc."

But I had also brought up the possibility that "electronic images of the surface scene outside offer, for good as well as mischief, the opportunity to be manipulated. The viewer may be able to select a sky color and brightness to his or her liking. The [tele]viewer [device], much like an Internet browser, would then 'interpret' the black areas at the top of the picture accordingly. Pick a light gray to go with the moontones, or a smoky blue. A visiting Martian pioneer, might prefer a dusty salmon. Homesick for Earth? Pick a brilliant blue. The idea is not to deceive oneself but to prevent eyestrain – if it has become a personal problem."

Technology now at hand

When I wrote that, I was making a leap of faith. But since, American Football fans have become familiar with a new computer-assisted TV trick that paves the way: the insertion of an orange line on the screen to show the viewer where the football has to be advanced for a "First Down." How do we get from this "scrimmage line" to our first down – the apparition of a blue sky on a visiscreen showing the moonscape outside one's homestead habitat? A smart computer program would scan the scene looking for the "horizon," able to distinguish between the black sky above that line and dark shadows below it. The viewer could control the result, the tint color, contrast, brightness, etc. And, of course, the viewer could turn the program off, preferring reality, however black.

Some years ago (a couple of decades, actually) I bought a pair of "rain glasses" that had the effect of brightening the view and giving it a distinctive yellow cast, creating for a moment the illusion that the sun was shining. They were fun to wear for a while, then I threw them away, preferring reality.

Some of us are more affected by cloudy and rainy and otherwise “dreary” days than others. Moi? I have always been able to make my own sunshine. Some pioneers will handle the black skies well, and need no artificial assistance to “pretend.” Others may want to wean themselves of blue skies gradually, and such smart screen moonscape monitors will be available with a “blue skies patch.” Software is all we are talking about.

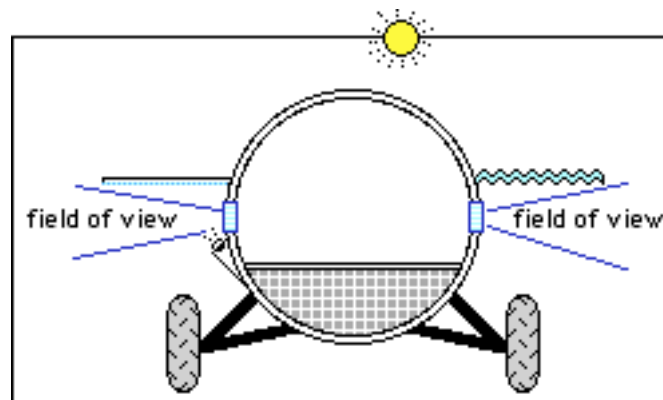
There just might be competition among software providers. The introductory program would just shade the black sky uniformly blue. Improvements would make the sky a deeper blue below and a milkier blue near the horizon. But then comes the fun! Programs that can be set to randomly insert alien space ship landings, or balloons, or World War I biplanes, or geese flying south in formation, or clouds of various types, even storms, lightning and more. It might amuse the kids, but perhaps most adults would tire of the “let’s pretend” games fairly quickly.

Out of the Homestead and into the Rover

Most Lunans, in their every day work and recreation schedules will rarely venture out-vac, beyond the airlock onto the surface, or even through the dockport matchlock into a pressurized rover for an excursion or to travel to another settlement. But when they do, they will have much less to distract them from the view out the porthole or visiscreen. If some manage to pay little attention to the outscapes in their daily routines, once out on the surface, on the way to somewhere else, it’ll be harder not to notice.

Yet, with highway rights of way being free for the taking, once traffic volume allows, coaches may be very wide track, to the point of having twin aisles like our wide-body jets. Those who do not care to look out the window will have plenty of opportunity to sit “in the middle.”

For those who do want to see where they are going and to appreciate the moonscapes, there are at least two options that would “moderate” the starkness of the view, the black skies in particular. There could be the smart flat screen monitors built into the seat back in front with the sky-effects fully controlled by the passenger. For “window seat passengers,” the porthole could sport a sort of “visor” that would project outwards, blocking most of the sky to within perhaps 10–15 degrees of the horizon. Its underside could be a light matte blue, lit from a lamp below the window. Or it could be made of a special light diffusing glass such as we mentioned as an option for skylights, if such a glass proves possible to manufacture.



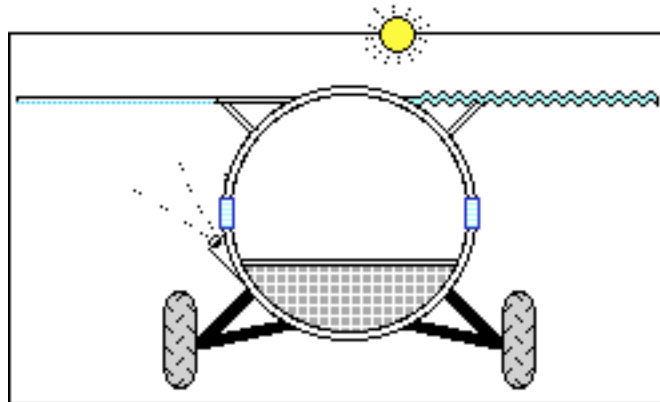
ABOVE: On the left, an uplit visor with a blue matte underside masks much of the black sky at left. **At right,** a sun light diffusing glass visor does the trick naturally.

How might frequent traveler’s react to devices like these? Reactions might run the gamut from “Why should we pretend this is not the Moon?” to “Wonderful!” to “You need to tone it down a bit.” to “Junk the fake clouds.” We differ in our tastes and tolerances. Market forces will determine what stays and what goes. One coach, on a busy route, might be equipped with several options, to test the market waters.

The convenience of passengers is far less a concern than that of drivers, however. Eye strain can affect safety. So whatever the fate of such passenger window visors, we predict that driver windshields will be visored somehow, or visiscreens, equipped with sky effects programs such as those described above, will replace windshields.

Yet another option is a wide-eave micrometeorite canopy, either underlit or sunlight diffusing that leaves black only the horizon-hugging area of the sky. Such a shield makes sense: while some

micro-meteorites will travel in low-angles hugging the horizon, and sneak under any canopies, most of them, coming in at higher angles, would be intercepted, greatly reducing abrasion of vehicle windows.



We will lick those "Black Sky Blues!" <MMM>

Music to Watch Moonscapes By

By Peter Kokh

With the new Lockheed/Tom Hanks IMAX film "Magnificent Desolation" featuring the video footage shot on the Apollo Moon Landing Missions due to be released soon, I eagerly anticipate the background music selection (or will the music be specially commissioned?) as much as the promised "put you right there" visual experience. Music can endow lifeless scenes with undefinable significance, affecting our impressions far more than we might admit.

Will composers write symphonies, overtures, and theme music with the moonscapes as inspiration? Why not? Should not the pioneers have their own counterparts to Antonin Dvorak's "Symphony from the New World?"

Or "The Grand Canyon Suite" by Ferde Grofe? While we could look for suitable existing pieces (as was done for 2001: A Space Odyssey) fresh compositions which would be forever identified with the lunar frontier and become part of frontier culture are preferable and will come in time. Some such music could be written now. Certainly the actual pioneers will add to whatever we provide as start.

A Challenge to Computer Music Composers

Imagine a computer program that would blend a whole range of themes keyed to many different moonscape features: topographic features such as craters, rilles, mountains, mare planes, rolling highlands, boulders and shadows; geochemical features such as various types of regolith, and automatically interweave them, each given proper prominence or understated subtlety according to the changing scene outside one's vehicle window? A tall order? Yes! Such a computer program would "read" the passing terrain much as a music box reads the spikes on a rotating drum or disk.

Themes keyed to scene components are not new. Just think of "Peter and the Wolf" by Prokofiev. Yes, from that classical piece to the sort of "Music of the Terrain" readers that translate shapes, colors, textural nuances into music is quite a leap. Surely someone is up to the challenge!

For this idea, I give credit to William K. Hartmann who wrote in his recent science fiction mystery novel "Mars Underground" page 185 (paperback edition):

"Flat-lit by the high sun, the plain looked like a giant's sheet of music, with rocks scattered like notes that would play some strange music if only you knew how to read it."

There is more than one solution to this equation. Different composers could use different instruments and different themes for the various types of terrain features and shadings. Listeners would set the relative volume or stress according to which features are of most interest.

At night, there could be a program that keyed in to black lit phosphorescence perhaps. The bottom line is that music can bring the barren desolation to life. <MMM>

WEATHER FORECASTING ON THE MOON

By Peter Kokh

Talk about the weather!

The very idea of a weather bureau issuing forecasts for Lunar pioneers at first blush seems absurd. “No atmosphere, no weather,” it’s a no brainer! Either the Sun is out and you can’t see the stars in the black sky for all the glare, or it’s Nightspan and stargazing still is not that good when Earth, 60 times brighter than the Moon is for us phase-for-phase, makes stargazing less than rewarding also. Unless you are on Farside during local Nightspan, where the Milky Way is so awesomely brilliant it wants to suck you up into its bosom! Talk about star travel!

But seriously, no thunderstorms, no lightning, no hail, no tornados, no hurricanes, cyclones or typhoons – no tropical storms period, no blasts of Arctic cold: nothing but the boringly predictable cycling of Nightspan and Dayspan, of superficial heat and superficial cold.

All so true! On the other hand, the Moon is subject to Cosmic Weather events that for Earth, our atmosphere serves as a resilient shield. Cosmic Rays get through, of course, but on the Earth’s surface, Solar Flares and meteorite storms are scarcely felt, though we can observe their rites of passage through the atmosphere: the auroras and the Meteor Showers – neither of which will be visible phenomena on the Moon.

Both Solar Flares and some of the denser Meteorite swarms will make the morning and evening news on frontier radio, television, and internet stations. For Solar Flare events, travel restrictions will apply. No one should be further than an hours drive from the nearest flare shelter. But perhaps there will be meteorite shower alerts only for spacesuit pedestrians out on the surface without the protection that even a covered rover can provide.

Sounds pretty boring. They better come up with a panoply of sporting events or else no one will have anything to talk about other than political scandals, and who got pregnant by whom. Weather for us, even when it is rather nice, is a great ice-cutter for starting up a conversation. Pioneers fresh from Earth will miss it. “Hey, what about this weather?” will become a popular inside joke.

We have nonetheless found enough to talk about concerning Moon Weather to feed two past articles: MMM #5, May ‘87 “Weather” – find it in MMM Classics #1 – MMM #148 Sept. ‘01, p. 7, “Music of the Lunar Spheres”

www.moonsociety.org/members/mmm/mmm148_Sep2001.pdf

Twin eternal dust storms, circling the Moon forever

Three decades of data from an instrument left behind by the Apollo 17 crew, intended to track dust from meteorite instruments, have instead revealed an unexpected phenomenon. The instrument, called LEAM for Lunar Ejecta And Meteorites, has been gathering data since 1972. As the rising Sun sweeps the surface that has been in darkness for almost 15 days, an electrostatic effect levitates some of the loose fine particles. Looking at the Moon along the sunrise terminator, imagine one long linear storm or suspended dust stretches from pole to pole, a distance of almost 3,400 miles. As the terminator advances, the storm follows, but like the phenomenon of a wave traveling through water, new particles rise at the front replacing others that settle at the rear. The storm follows the sunrise terminator around and around and around, circling every 29.5306 days. It has been going on, apparently, for billions of years.

All the Apollo landings occurred, complete with takeoff, during midmorning lighting conditions. NASA wished to avoid the long shadows of dawn, the high heat of midday, and the cold of night. No astronaut has experience this storm. We have a lot to learn about it. How dense are the particles? How much do they obscure vision? How much of a problem will they pose for astronauts, explorers, and settlers? Will the levitated dust insinuate itself into space suit joints, will it clog up vehicle lubricants? Will it abrade windshield glass? We don’t know and we need to know.

NASA intends to send crews to a polar site, where, if there is a similar opposite effect along the sunset terminator, the two storms will link up playing crack-the-whip. Or they may peter out closer to the poles. We don’t know.

A commercial base, constrained by economic sense and the resource needs of diversified industrial development would hardly choose a polar cul-de-sac site only to developmentally handicap itself. So commercial astronauts are likely to experience this wispy sinuous dust storm rolls every morning, once a sunth (lunar month = 29.5306 days). But we are not even sure that they will see it without spe-

cial equipment. The swirls of dust may be so wispy as to be invisible to the naked eye, at least to the untrained eye.

It seems we need to send a new instrument package designed to answer our questions. Right now all we have is some tentative theories. Timothy Stubbs of the Solar System Exploration Division at NASA's Goddard Space Flight Center suggests the explanation may be that "the dayside of the moon is positively charged; the nightside is negatively charged. At the interface between night and day, electrostatically charged dust would be pushed across the terminator sideways, by horizontal electric fields.'

But we don't really know. It's not just a matter of scientific curiosity. We need to know if it poses a problem for equipment and for personnel out on the surface. If it does, we need to figure out how to work around it. We will be at home on the Moon, only when all its dangers become so well known that we act appropriately as it by second nature. That day will come! <MMM>

Source: http://science.nasa.gov/headlines/y2005/07dec_moonstorms.htm

MMM #206 - June 2007

Sweet Spot for Lunar Surface Sports?

By Peter Kokh



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

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

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

Sweet Spot Discovery?

Well, scientists have discovered one area on the nearside that has a small residual magnetic field, an area located at 57.8° West, 8.1° North, in the Ocean of Storms Oceanus Procellarum, on the

near (visible) side of the Moon, and has an extension of approximately 30 by 60 kilometers. (18x36 miles). This area is known as **Reiner Gamma**.

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

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



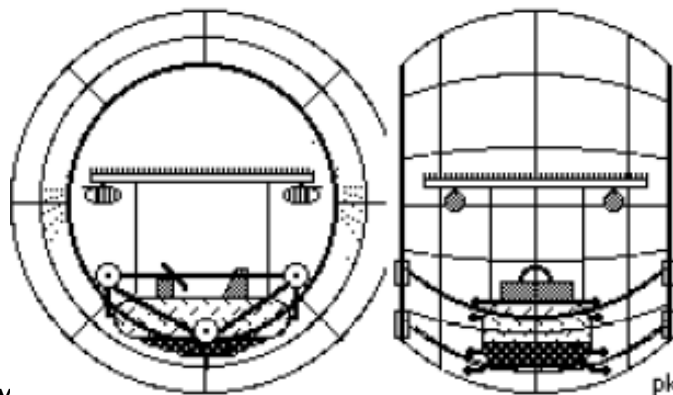
Vacationer barbecuing on cottage patio under glass vault to expose the lunar skies

Illustration by David E. Cremer ©1989 Lunar Reclamation Society

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

Possibilities for this “Out-vac Recreation Mecca”

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



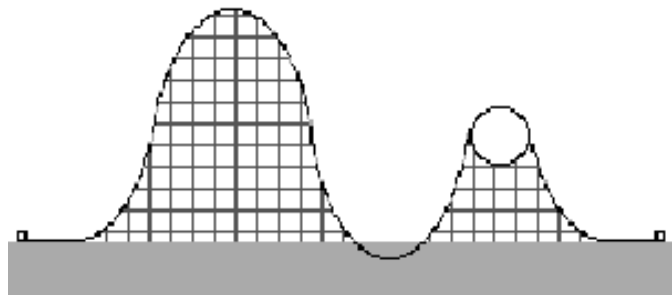
Lunar “surrey

pk with the fringe on top”

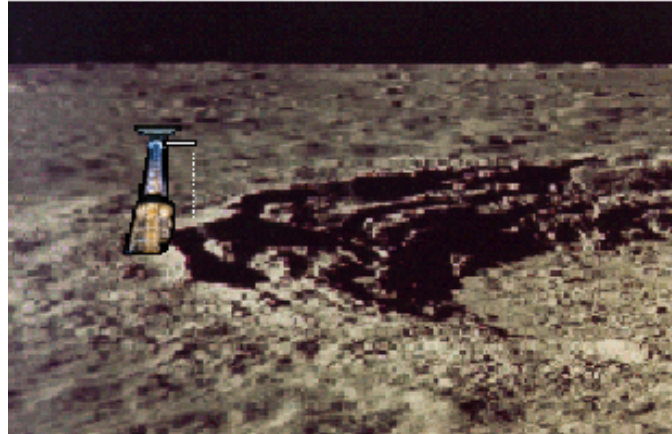
Watched “American Gladiators” lately? Have you seen the “Atlasball” segment? Next time picture space suited lunar thrill-seekers working their geodesic cages along a rally course of craterlets etc. Might be fun if the sweat of exertion and then overheating inside one’s space suit could be handled!

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

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



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



Observation Tower with Revolving Restaurant at Crater edge, with bungee cord jump point
– Copernicus shown, but could be anywhere

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

Confirming or debunking this Daydream

What is needed is a lander/rover to to measure the radiation flux inside and outside of this oval area, starting at the center, then proceeding to and past the edge on the shortest route along the ellipse short axis. Would a future lunar tourist company pay for such a survey? If a billion dollar resort complex was at stake, of course! On the other hand, NASA might be interested in the data for "science' sake," and pick up some of the tab.

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

MMM #210 – November 2007

It's Time for some wild, but just possible FICTION –
http://www.moonsociety.org/humor/afd_news.html#hh

It Came From the Bowels of the Moon

A Science-Speculation Essay by Peter Kokh

[a fun piece written for a Milwaukee Horror Con "It Came from Lake Michigan" the weekend before Halloween]

Many of us believe that it is likely that "other intelligent species" have come this way before. Perhaps as explorers, maybe as pioneers, or in search of lucrative trade. Maybe even as imperialists. Earth has been around for some 4.6 billion years having formed more than eight billion years after the first stars. Plenty of time for other, earlier civilizations to have risen and perished in that time. Astronomers believe that earlier stars and their planetary systems were less rich in the elements that form rocky worlds like ours. Yet that some may have not enjoyed life long before ourselves seems inconceivable.

Let's suppose for sake of argument, that we have been visited a hundred times since Earth was formed. Averaged out, that's one visit every 46 million years. And there is a 50-50 chance we have been visited as recently as 23 million years ago, and a 1 in 100 chance that someone came calling as late as 460,000 years ago.

Hmmm!? Now there is a problem with averaging things out that way. For one thing, the pace of visits should have started much more leisurely as "way back then" there were likely fewer intelligent civilizations than we imagine that there must be today. Then the pace gradually picked up. So the interval between visits may have decreased on a logarithmic scale. But who knows? Maybe we got lucky enough to have had a visit in the past ten thousand or so years since the ice age and the birth of human civilization as we know it. But also possibly, the Sun and Earth have been in the "boondocks," off the logical routes of interstellar exploration and expansion. All we can do is wonder "for the sake of argument."

Perhaps that 100 times in the lifetime of Planet Earth is too pessimistic. Perhaps it is too optimistic. One thing is sure. Time, and by that we mean the amount of time before the present, is as vast as space. The two go hand in hand. The chances of finding a contemporary civilization, one both nearby in space and nearby in time, are much slimmer than that of identifying a civilization whose Sun was once a neighbor of ours but which has either drifted far away, or that civilization has long succumbed to the ravages of time; much slimmer too than finding a contemporary civilization, contemporary in that we now detect its signals, though it is so far away that it too may have passed into oblivion since the message was sent.

But, again, for the sake of argument, let's say that our solar system has indeed been visited, explored, inspected, mapped, catalogued, etc. Let's say that this has happened more than once. Still the odds are over-whelming that our last visit might have occurred before the rise of modern man, cultural man, technologically inventive and scientifically curious man. This "last visit" could have occurred in the past 5 million years, at a time when the evidence of simian and primates was clear and the evidence that Earth would soon bring forth its own dominant species, a species which like there own, could alone help their homeworld's "Life" sprout elsewhere throughout their system and beyond. What message could have been left?

But just as plausibly, our last visitors may have come calling much earlier: in the age of the dinosaurs, or even earlier when multicellular life was first forming in the oceans and seas. But it might have been clear to the visitors even then that this young Earthlife had the potential to go all the way -- in time. What message for a far far future Earth-dominant species could the visitors have left, should they so have felt inclined?

That's one question. Another is where could they possibly have left a message or a calling card, even a "Cheshire Smile" for us to know that someone from somewhere and somewhen had come calling? Where could they have left it where it would not have been destroyed by the ravages of Earth's active geology and weather? Nowhere on Earth!

When Apollo 15 moonwalkers, David Scott and James Irwin, landed along side a portion of the meandering lunar valley known as Hadley Rille, they looked for clues to its origin. Running water could not have carved the valley. It was too winding to be a fault line. Soon, lunar geologists, or "selenologists," came to a unanimous conclusion. The rilles all appeared as features of various maria, frozen lava plains. The evidence was clear that the lava sheets have must have had little viscosity, or they would not have spread hundreds of miles. On Earth we find these kind of lava plains also, for example in the Pacific Northwest. How the lava sheets spread is by rivers of lava. The top exposed to the cold of atmosphere, or on the Moon, the greater cold of space, soon congeals, then the sides. When the flooding has stopped, a lava tube is left. Some of these, too near the surface, collapse and become winding ditches. But whoa! On Earth lavatubes are typically 10-30 yards across and just about as high. If Hadley Rille was a collapsed lavatube, that tube must have been gargantuan, hundreds of yards across or more. Scientists soon realized that this could and would happen in the Moon's lighter gravity, just one sixth of our own.

Next question. Are all the original lavatubes collapsed? No! We see clear proof that at least some segments are intact, and probably whole tubes. Near the center of the Nearside lies Hyginus Rille, wandering for hundreds of miles. But here and there are interruptions, places where the rille "stops" and then, miles ahead, "starts" again. Those interruptions look like land bridges over the rille. Indeed, they are uncollapsed tube sections.

Now all the maria must have formed that way, but we do not see rilles everywhere. There must be many places where the original tubes are still intact with no surface entrances. Indeed, some maria formed layer upon layer. It is possible that each layer has intact lavatubes, gargantuan voids tens of miles long -- or longer. The Moon has bowels!

Someday, these "hidden valleys of the Moon" may harbor industrial parks, farms, even human settlements. What else? Well consider that they all were formed 2.5 and 3.8 billion years ago. They have been intact for an inconceivably long time. What a place to put the Grand Archives of All Mankind, even of all Earth Life! There, these records and artifacts would rest without decay in the cold black vacuum of these voids, until the Moon ceased to be. And there you have your answer. Our visitors could have left us an incomprehensible gift, safe until we became mature enough to find them.

Okay, we answered the 2nd question first: Where could visitors have left a message or record for us to find that would have been able to survive the ravages of time: geology and weather? In an uncollapsed lunar lavatube. Those that were intact would have been intact for billions of years already and should be for billions of years to come! Talk about security!

Now back to the first question: What would they have wanted to leave behind for us, whoever and whatever we turned out to be? Now, of course, many of us Star trek fans know the answer. The Prime Directive would not only have mandated that we not find what they left behind until we were advanced enough to appreciate it, but that they not leave behind anything which would short-cut our own scientific and technological evolution but also anything which might play havoc with our culture or cultures. Yes there are skeptics and cynics, but it may well be that the only civilizations that survive to become spacefaring will have come to appreciate the hard way, as we have, that the Prime Directive is not something Gene Rodenberry thought up, but which intelligent species everywhere must come to appreciate. The wreckage of primitive cultures in our own past is evidence enough.

Suppose we believers in the Prime Directive are on to something? I propose that this would boil down to two simple guidelines: (1) tell the natives nothing about ourselves; (2) tell them instead about the past of their world; preserve for them records of that past that otherwise would be sure to be erased by plate tectonics and weather. In other words, all we, as the visiting species, leave behind of ourselves, is a "Cheshire Smile." That is how I propose the visitors, any one advanced enough to have wandered by, will look upon the opportunity. Here it is there message to us in their own thoughts.

"You will know that we have been here, that we foresaw the probability of the rise of a dominant species that could carry its planet's life beyond its spatial shores, and that we cared to give you a gift of knowledge about the state in which we found your planet when we passed by: the shape and position of its continents; mountains, and rivers, and lakes, and ocean trenches; the volcanic hot spots and rifts and plate boundaries; the weather and climate; detailed depictions and models of all the life forms, plant and animal and even microbial, that we inspected. These are things you could never discover, no matter how valiantly you tried to reconstruct your planet and biosphere's past from the partial and haphazardly scattered clues that time has left behind.

"More, we can leave you an atlas of your heavens as they were then. They were full of stars and star clusters and nebulae that may now have drifted halfway around the galaxy. We can show you your neighboring galaxies to compare with the distribution you find today.

"But no, we won't tell you where else we found life in our explorations. No, we won't describe ourselves, our physiologies, our cultures, religions, or histories. But what can be more than to know just simply that we were here, looked forward to your emergence, and cared enough to reveal some of your very own past?"

So there you have it. The greatest find of all time, and maybe for all time to come, will have **come from the Bowels of the Moon!** - PK

MMM #214 - April 2008

Protecting Lunar Surface Facilities from Sandblasting by Landing Rockets

by Peter Kokh

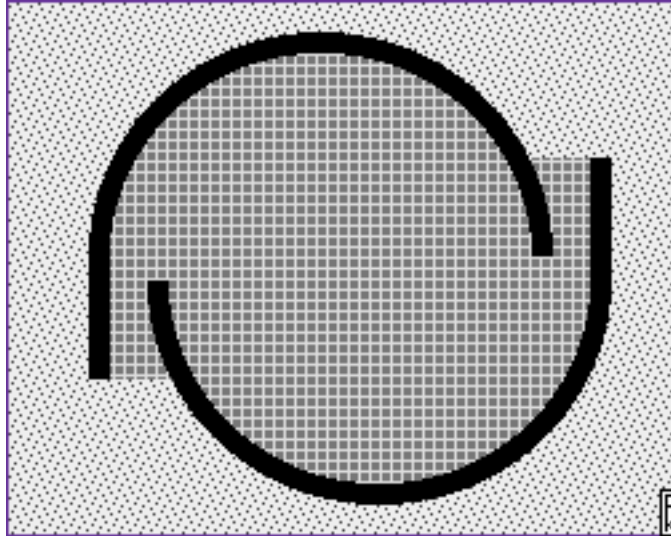
www.space.com/scienceastronomy/080212-st-lunar-sandblast.html

The evidence

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

The verdict

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



Neutralizing the problem

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

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

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

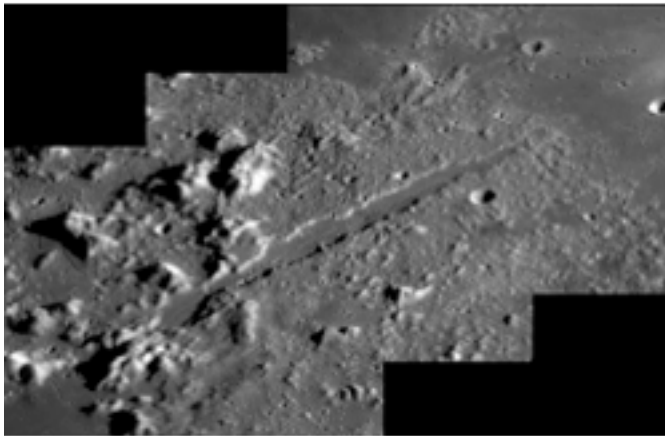
MMM #215 – May 2008

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

By Peter Kokh

It would be ideal if we could identify all the most scenically and geologically "special" features on the Moon and classify them into those that can be visited but not developed ("leave but footprints, take but photos") and those "common" and "mundane" enough to warrant consideration for development. Ideal! Unfortunately, sometimes very scenic areas, by their very nature also happen to be "in the at" of

logical traffic routes, or, as in our case in this article, a logical transportation route precisely because of what makes it scenic and special.



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

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

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

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

To the point of the article, Mare Frigoris has access to the rest of the nearside “mare-plex” in three locations: (1) far to the west through Sinus Roris (Bay of Dew) into Oceanus Procellarum (Ocean of Storms) and points south; (2) far to the East via Lacus Mortis (Lake of Death) and Lacus Somniorum (Lake of Dreams) into Mare Serenitatis (Sea of Serenity) and points south; and (3) in the middle via Valles Alpines (Alpine Valley) into Mare Imbrium (Sea of Rains) and points south.

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

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

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

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

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

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

Anyone want to get a lunar National Parks Group going? kokhmmm@aol.com

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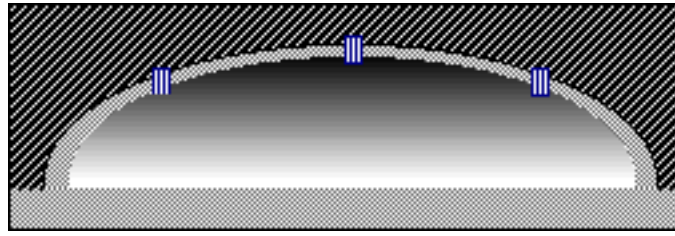
MMM #225 – May 2009



By Peter Kokh kokhmmm@aol.com

In his latest book, “**How to Live on Mars**” Robert Zubrin comes to the topic of skinsuits, that hug the body, allowing much greater freedom of movement, and with much less fatigue. That’s the good part!

While skinsuits will most likely be inferior when it comes to handling radiation and thermal extremes, these dangers are excluded in sheltered or shielded “lee” vacuum situations within lava tubes and in unpressurized warehouses and sports arenas (illustration below) that are sheltered from the cosmic weather. It is in these environments that we are to see widespread skinsuit use. Such suits are lightweight in comparison and allow much greater freedom of movement. More comfortable to wear, they will allow people to work and recreate for longer periods without becoming tired or exhausted.



See www.moonsociety.org/images/changing/lee-vac_arena.gif

Skinsuits are revealing

But we gain this comfort and ease at the price of embarrassment. Because a skinsuit is formfitting, it will showcase all the varied imperfections of one's own body shape. Potbellies, wide hips, flat breasts would all be revealed. Some of us will take that in stride. Others would predictably not be caught dead wearing such a suit.

Or so Bob Zubrin predicts! But there is an answer: lightweight outerwear that can partially moderate body shapes, and distract with color and pattern as well.

Skinsuit "Outerwear"

There could be hats, capes, robes, overalls; you name it. Meant for wear in vacuum over a skinsuit, these apparel items could be made of most anything cheap and easy to work with: woven metal fibers, even wires, yes even medieval style chain mail; scrap cardboard, fiber glass fabrics, metal plates strung together - the adventures of "trashure" (transforming trash into treasure.) Any material or style that will distract attention from bodily imperfections, yet not make movement cumbersome or awkward, will become something with which to experiment. And for inspiration; anything from historical periods, from science-fiction/fantasy, from imagination is fair inspiration for creative designers.



One can imagine periodic fashion shows in Luna City, perhaps in a lee-vac arena, where models with very imperfect physiques, both male and female, would strut down a runway before onlookers behind glass observation areas, with a variety of materials, colors and designs. Over a skinsuit, of course! Whether stylish, fanciful, sheer fun, what does it matter? Skinsuit outerwear fashions will say, "We belong here, out on the moonscapes!"

This may become an anticipated periodic event even for those not anticipating lee-vac or out-vac excursions. With successive shows, and over the years, skinsuit "outerwear" items available in Luna City retail shops will grow in number, design variety, and sophistication.

Start of a Cottage Industry

Periodic fashion shows should be popular, and drive a startup cottage outerwear fashions industry. Over time, ever more pioneers, whatever their physique, will feel encouraged to explore what the out-vac and lee-vac environments have to offer. And for those venturing out, the great variety of

outerwear fashions would make emergency identification easier, and people watching that much more fun.

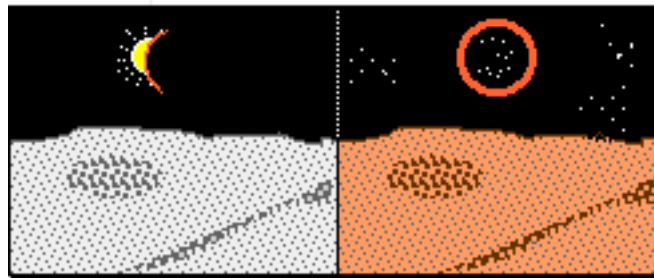
Skinsuit outerwear and new performing arts

Lee-vac activities would become more varied as well. Can you imagine ballet not only in one-sixth G, but in vacuum as well? Lee-vac arena sports team uniforms would be more interesting and fanciful as well – all part of team sports enjoyment.

Beyond the protection of “lee” space

But these “fashion” developments might also encourage more and more lunar residents to wear skin-suits with outerwear even in full out-vac, the unprotected “vac”uum “out” on the lunar surface. Such sorties would be less risky during the “moderate risk” conditions of “early morning” days and “late evening” long shadow days. Remember it is not quite 15 days from lunar sunrise to sunset! Temperatures will be lower, but not the radiation level.

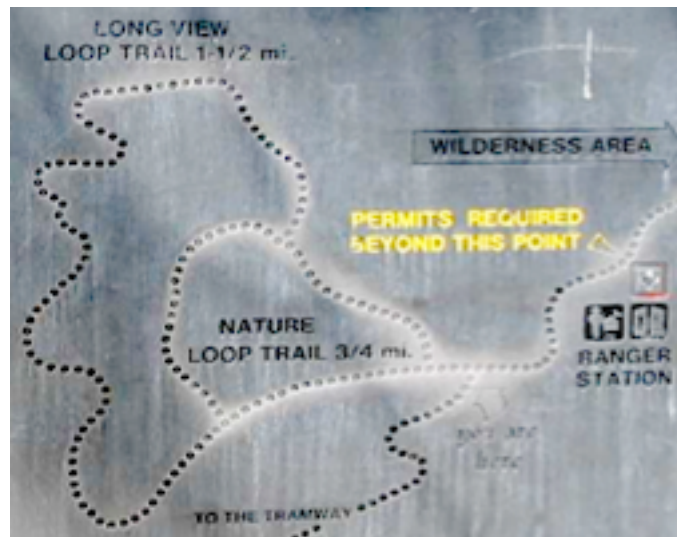
Another “low risk” opportunity lies during the 1–3 hour long solar eclipses when the surface of the Moon is lit with the ruddy light of the ring of sunrises and sunsets that circle Earth when Earth itself is blocked out as the sun slips behind it. (An event paired with total lunar eclipses seen on Earth.) During such periods, the out-vac will take on the appearance of Marscapes in twilight!



Every now and then, Earth-facing Moonscapes take on the hues of a dimly lit Mars. But there will be no mistaking where you are. In the sky in place of Earth will be a black hole outlined with a ring of orange tones with only one ten thousandth the brilliance of sunlight. And in that black hole, clusters of lights, Earth’s cities and fires, dotting otherwise dark continents. It is Umbra. * See MMM #164 p. # – APR 2003.

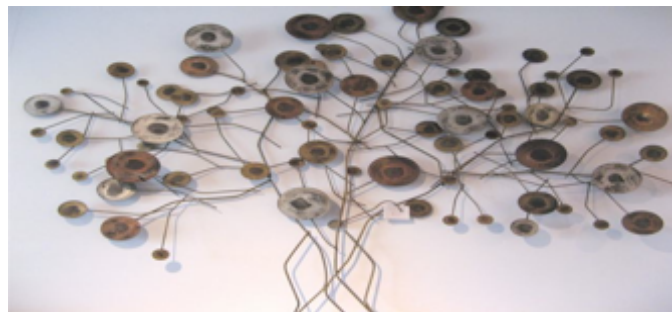
Surface paths and trails for strolling

But before such surface recreational strolls can become popular there needs to be some encouragement in the form of “excuses to venture out:” something worth going out on the surface to see and experience. Most people will not just wander out on trackless wastes just for the sake of doing so, at least not often! But Luna City Fathers can encourage people to get out from the confines of the settlement encouraging the creation of “nature” paths that showcase local geological features of interest. Compacted and sintered, these paths will be relatively dust free yet allow enjoyment of the “natural” moonscapes to either side. Such a path could encircle the settlement, with bridges and underpasses where the path intersects roads into and out of the settlement. After sundown, rocks and cut breccias selected for phosphorescence could trace the way.



Art and Sculpture along the way

Sculptures of an ever more varied variety and originality along such paths could also attract ex-pedestrians. In turn, the opportunity to have their works seen and admired by many will encourage art-ists and sculptors to create objects of interest and fascination



Fanciful metal sculpture "moon shrub?"



Free scrap metal is manna from heaven for sculptors

There could also be benches, each of a unique design (how about a pioneer design competition to stir extra interest?) and an objet d'art in itself would encourage walkers to take a rest, the better to appreciate the art and views along the way.

Animated Sculpture

On Earth, mobile sculptures are powered by the wind or sun. On the Moon, the solar wind blows at hundreds of miles per second, but is too thin and lacks the oomph to power anything. What about solar power? Solar panels could easily drive small motors and actuators to create mobile sculptures on

moonscape paths and trails frequented by walkers after sunrise and before sundown. They'd work during high noon, of course, but few people would venture out on the trails at those times.

Let's use our imagination! Solar powered animatronic guides to explain landscape, rock, and geological features? Even programmed to answer routine questions? {"Where is the nearest restroom?" "Are there any vending machines nearby?"). Why not fanciful alien creatures that would leap out from behind a boulder to scare and delight children? Halloween when it occurs near local sunset could become a trail-event must!

The oldest, easiest hobby?

But perhaps the most interesting things to observe and study will be provided by the walkers themselves. They will no doubt appreciate this special opportunity to partake in the perhaps humanity's oldest hobby: going somewhere just to see and be seen – people watching! "Oh look at what she's wearing!" "If he thinks we can't see that he has a potbelly, he's fooling himself."

Bringing the Lunar Frontier to life while preventing neurosis and psychosis

Is all this idle diversion? What has all this got to do with anything? Getting pioneers to venture outside the pressure hulls of their settlement is absolutely vital to the long term mental health not just of individuals, but of future lunar frontier society in general. We on Earth see the lunar surface as hostile, barren, life squelching, and something to be avoided at all costs. To tell the truth, those of us who see it that way are poor settler material.

It is imperative that the pioneers learn to make themselves feel "at home" on the Moon not just within their comfortable settlement homes and common spaces, but out on the surface as well.

The penalty of not doing so will be neurosis and psychosis not just of individuals, but very likely of lunar frontier society in general. If we are going to make ourselves at home, we need to do it in a "no holds barred" fashion.

- Life-squelching cosmic rays and solar flares?
- Tissue-burning ultraviolet?
- The incessant micrometeorite rain?
- The insidious, potentially poisonous moondust?

A lesson I learned from my mother is that "every apparent disadvantage remains so as long as we are looking at it wrong." "Change your attitude and try to see how that feature can be turned into an opportunity!" Then you will see it in its true light for the first time!

Not a common attitude to be sure, but try it! It works. Now that's the stuff of which those pioneers who will survive and strive will be made of. Attitude is everything, and the naysayer, the timid, the "Oh, we can't ..." crowd just doesn't get it, doesn't understand, and we have to ignore them and move on. The Lunar Frontier is our dream not theirs, and it is ours to pursue. The above attitude works on everything: from apparent life setbacks to obstacles on the road to the Moon and beyond.

Beyond the visions of "fellow travelers"

Some "pro-space" writers want to see robots do everything. "There is no need to put humans in such alien and hostile and godforsaken places," they advise.

But they have it all wrong. Venturing into new turf, into spaces that at first seem hostile to human life, is something we have been doing even before leaving our home world in Africa to settle the rain forest jungles and the parched deserts of the first human continent, in a journey that would someday see us settle the north arctic which would have seemed as life-squelching to an early African in what is now Kenya, as life on the Moon must now seem to many of us incapable of getting past intimidating first impressions.

We have got to where we now find ourselves, a truly global species, by venturing into one new land after the other, where the wildlife, the vegetation, the climate, and the available resources were different from where we came from, from what we were used to and had taken for granted. And guess what? Each time we learned to make ourselves at home. Each time we learned to live with the "dangers" and "challenges" posed by the new territory.

From a more meta-historical vantage point, each time we developed ever more of our amazingly adaptive unsuspected human potential. Each time we realized more hidden human talents. Each time we brought out more of the potential that gives glory to the creative agency or agencies that have driven us and drawn us forward and upward. Why would some put a cap on what we humans can do? A cap based on past accomplishments in Africa 200,000 years ago would have been quite immature. A cap based on our accomplishments to date in the early 21st Century would be just as pre-mature. Our fellow travel-

ers, those who would see robots explore space and access its resources but leave humans at home, are just that. Fellow travelers. We can use their limited support, but we must never accept the limits of their vision.

So you thought that this would be just a “far out” article on whimsical spacesuit outerwear fashion! Every-thing bears on everything else. Where we are and where we will be in the future is a web of endlessly varied possibilities. Let the adventure never end!

The Moon, its capacity to support a full flowering of human life quite unsuspected, will be the first of many new worlds. Why should this surprise anyone. Every element in our bodies, and in every-thing we see around us, other than hydrogen which is primordial, originated in the furnaces of star core explosions.

“Of stardust thou art – And to the Stars thou shalt return”

Now that is a “pilgrimage”, a “directive”, that will take us centuries, millennia, maybe eons to pursue. We are at the “baby’s first steps” stage, the most critical of all. We have yet to truly integrate Antarctica into our human metaworld, and timidity, self-doubt, and endless diversions threaten to stifle our next frontier-exploring efforts. Are humans up to the challenge? Despite every thing that should give us pause, a look at our past should encourage us. We have always taken that next step and we have always succeeded. Now is certainly not the time to doubt either our own capacities our our des-tiny.

But each time, only a few pioneer the new “world” and they do so despite the discouragement and disinterest of the many who remain behind. <MMM>

MMM #234 – April 2010

Lunar Thermal Wadis & Exploration Rovers

MMM Special Report by Peter Kokh

NASA Lunar Surface Systems Concepts February 25–27, 2009

http://www.nasa.gov/pdf/314555main_AIAA-2009-1339-125_Thermal_Wadi.pdf

“wadi” is an Arabic term common in Syria and Northern Africa for a watercourse that is only inter-mittently flowing with water, and is otherwise dry, often with wet soil below a dried surface. An oa-sis. The Sudanese city of Wadi Haifa gets its name from such a feature.

Here the term is applied by analogy.

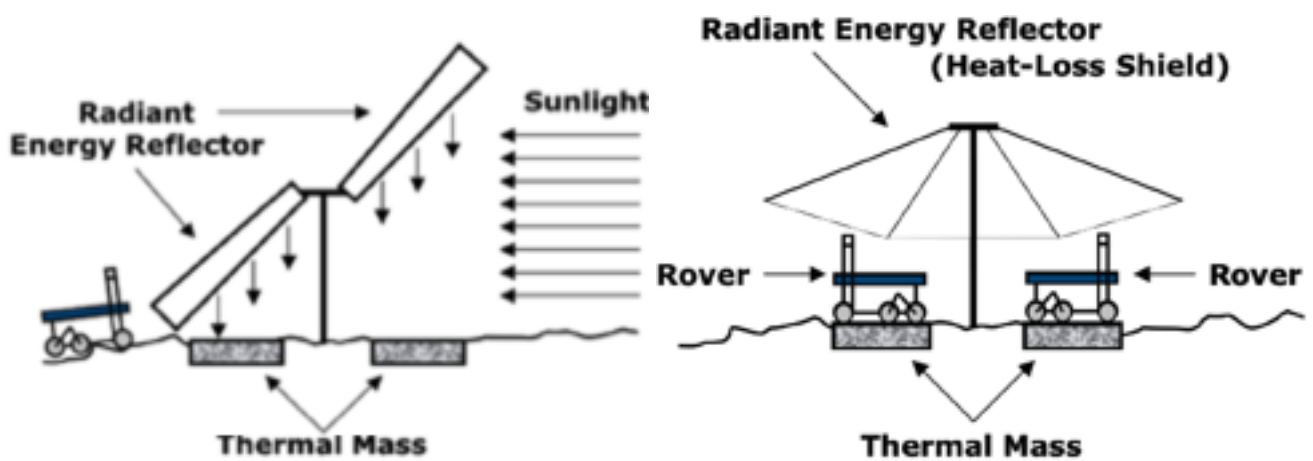
Source: Analysis of Solar-Heated Thermal Wadis to Support Extended-Duration Lunar Explora-tion – AIAA 2009-1339

Excerpt from the above:

“Among the many challenges that renewed exploration of the Moon is the survival of lunar surface assets during periods of darkness when the lunar environment is very cold.

“Thermal wadis are **engineered sources of stored solar energy using modified lunar regolith as a thermal storage mass** that can enable the operation of lightweight robotic rovers or other assets in cold, dark environments without incurring potential mass, cost, and risk penalties asso-ciated with various onboard sources of thermal energy.”

“Thermal wadi-assisted lunar rovers can conduct a variety of long-duration missions including exploration site surveys; teleoperated, crew-directed, or autonomous scientific expeditions; and logis-tics support for crewed exploration. This paper describes a thermal analysis of thermal wadi perform-ance based on the known solar illumination of the moon and estimates of producible thermal properties of modified lunar regolith. Analysis was performed for the lunar equatorial region and for a potential Outpost location near the lunar South Pole. The results are presented in some detail in the paper and indicate that thermal wadis can provide the desired thermal energy reserve, with significant margin, for the survival of rovers or other equipment during periods of darkness.”



Left: a sun-tracking reflector directs sunlight onto a thermal mass during periods of solar illumination while rovers conduct lunar surface operations.

Right: a heat-loss shield to limit radiative losses to space.



Above: The setting sun illuminates a rover parked on its prepared pad of heat-retaining compacted soil under an umbrella that retards heat radiation to cold black space.

Excerpt: “The thermal property values of the thermal mass are critical to the effectiveness of the thermal wadi. In its native state, lunar regolith is a poor material for thermal energy storage. Due to its very low thermal diffusivity, ... per measurements made during the Apollo program, heat does not penetrate the lunar surface very deeply and is lost rapidly due to radiation during periods of darkness. It is this property that accounts, in part, for the large surface temperature swing during the Moon’s 27-day diurnal cycle.

“However, the regolith contains the elemental materials needed for a reasonable thermal energy storage medium, and experiments on Earth have demonstrated that solar and/or microwave energy can enable the necessary conversion processes. Examples of regolith processing methods that can produce thermal masses with improved thermal properties include:

- Compacting and sintering
- Melting processed or unprocessed regolith, then solidifying the melt into a solid block
- Incorporating hardware and/or materials with high-thermal conductivity and/or high-thermal capacity.
- Reducing regolith, by thermochemical or electrochemical means, to produce a metal-enriched product.

The paper goes into details on the relative merits of these options, the practicality of their use, and makes recommendations. Using the moon dust’s own assets to combat the harsh lunar environment, is a win-win option.

MMM



Salvaging the Google Lunar X-Prize “Also-Rans”

By David A. Dunlop,
Moon Society Director of Project Development

Google Lunar X-Prize –

www.googlelunarxprize.org/lunar/about-the-prize/introductory-video

www.googlelunarxprize.org/lunar/about-the-prize

www.googlelunarxprize.org/lunar/about-the-prize/rules-and-guidelines

www.googlelunarxprize.org/lunar/teams

Opportunities, Incentives, and Tools For New Lunar Science Missions

Google Lunar X-Prize Teams

- Twenty teams are now vying for Google Lunar X-Prizes. While only two teams at best will win the 1st and 2nd prizes, the other team programs may offer potential options for further development. If so, their investments to date should not be wasted.
- Their merits with regard to technological innovation or cost-efficient models should be not go untested simply because they were not the first or second to land on the Moon.
- GLXP teams that do not win 1st or 2nd prize will require incentives and support to continue advancing their projects to flight readiness status and actual flight to the Moon.
- These also-rans may present opportunities to “re-purpose” their lunar landers to deliver needed or desired science payloads to lunar surface.
- Evaluation of each team’s design should be made in terms of
 - Risk reduction,
 - Technical feasibility
 - Cost efficiency
 - Suitability as platforms for lunar science missions that should be supported by the various national space agencies for those teams open to a follow-on incentives program to the original GLXP program.
- NASA and ILEWG (International Lunar Exploration Working Group) partners should support lunar program approaches and incentives that foster both international and commercial collaborations.

Incentive Science Contracts are an example of how this could work

- \$50M incentives should be offered for delivery of ILN (**I**nternational **L**unar **N**etwork) science packages comprising laser retro-reflector cube, seismometer, lunar radiation monitors, and heat flow probes – <http://nasascience.nasa.gov/missions/iln>

Technology Incentives

- A. NASA and DOE should offer RTG technologies as a missions-enabling technology incentive to lunar rover missions that deliver long duration sorties on the models of Pathfinder, Spirit, and Opportunity, and which address high priority science objectives. This should be jointly competed by ESMD (NASA Exploration Science Mission Directorate) and SMD (NASA Science Mission Directorate).
http://en.wikipedia.org/wiki/Radioisotope_thermoelectric_generator

- B. Incentives should be created for technology demonstrations that use non- nuclear techniques to survive the lunar night cold temperature cycle, such as “Lunar Wadis” – see preceding article.
- C. Incentives should be offered and competed for principal investigators and teams which can demonstrate achievement of science goals that are on lunar science road map so that the process of lunar science missions development is more “granular” and financial “assets can be brought to the table” in consideration of lunar missions proposals by science investigators and teams whose instruments have been competitively qualified.

Open-Source Student Lunar Lander Engineering Missions

As a means of driving down the cost of lunar transportation and creating opportunities for the next generation of lunar engineers and scientists, the ILEWG nations should supports University-based engineering teams and networks working on a transparent open source basis.

Following the precedents of the ESMO (European Student Moon Orbiter) and ASMO (American Student Moon Orbiter), and **cubesat** projects ILEWG partner nations should all support at least one “open source” and “ITAR free” student lunar lander missions. This would create a pool of shared designs and platforms for engineering support of lunar landers and rovers and the expansion of the “lunar robotic village” by 2020.

These student lunar lander platforms should be cost justified by the requirement to deliver lunar a greater volume of lunar science packages to the surface, the need for technology demonstrations on the lunar surface, and the support of engineering workforce development goals.

An Open-Sources Science Proposals Database

An open data base for lunar science missions proposals should be created which identifies principal investigator, sponsoring organization, proposed science instruments, Their Technology Readiness Level, Lunar Science road Map Objectives, mass, power requirements, cost, so that the lunar community of interest is easy to identify and the lunar mission “market” potential for lunar science is transparent. This database should build on the Lunar Orphans Flight Test (LOFT) list of NASA Lunar Commercial Services Commercial Crew and Cargo Office and the ESA Lunar Science Proposals Solicitation lists. All ILEWG member agencies should be invited to support this database. **DAD**

MMM #238 – September 2010

Taking a Fresh Look at the Spacesuit Concept

By Peter Kokh

Background: in a previous article,

“Engaging the Surface with Moon suits instead of Spacesuits: Mother Nature has a Dress Code!”

MMM #151 Dec 2001 republished pp 2-5

http://www.moonsociety.org/publications/mmm_classics/mmmc16_July2007.pdf

We addressed some spacesuit issues. In this article, we take the discussion further.

The NASA Spacesuits developed for the Mercury, Gemini, and Apollo programs evolved quite naturally from high altitude aviation pressure suits. For use on the Moon, they had to be able to resist micrometeorite puncture and keep the astronauts cool in the rising mid-morning temperatures on the Moon. For short stays – the longest was only a few days – the radiation issue did not need to be addressed.

But it is clear that these suits had two functions: pressurization and protection. While the inner suit worn by astronauts did help contain physical body support, as they did not include a pressurized helmet or pressurized gloves, the outersuit with helmet and gloves was needed for both purposes: pressurization and protection.

Separating these two functions

However, if we separate these two functions, we might be on our way to a more rational design, more comfortable to wear, with greater freedom of movement, and yet with adequate puncture resistance and thermal management. We already have several experimental forms of the inner pressure suit: the “skinsuit,” also known as the Mechanical Counter Pressure (MCP) Suit.

Mars Society Australia launched a “marsskin” project: www.marssociety.org.au/marsskin.php

“An MCP suit would differ by exerting pressure on the body using formfitting elastic garments. Webb and Annis published the concept and early experiments of a MCP suit in 1967, and in 1971 described the first demonstration that highlighted the many advantages of the MCP approach. MCP garments were found to offer dramatic improvements to gas pressurized suits in reach, dexterity and tactility due to the replacement of stiff joints and bearings with light, flexible elastics. Further advantages included safety (because a tear or hole would remain a local defect rather than cause a catastrophic puncture), lower suit costs and vastly reduced weight and volume. MIT conducted flexibility tests with basic MCP elastics during the mid 1980’s and found MCP gloves to be measurably superior to gas-pressurized gloves.”

While this prior research seems dated, one can understand NASA’s on again/off again approach to space suit alternatives and development. The Return to the Moon has been an on again off again program: the first and second Bush space initiatives. And that is why space enthusiasts have taken the lead. In addition to the Mars Society Australia effort, we are proud to call attention to research done by crew member William Fung-Schwarz, Health & Safety Officer on the Moon Society’s “Artemis Moonbase Sim 1” 2-week exercise at the Mars Desert Research Station, as Crew 45, Feb. 26 – March 11, 2006. <http://desert.marssociety.org/fs05/> (scroll down to #45)

The project goals, goal status, suit description, and costs are stated in William’s report: <http://desert.marssociety.org/MDRS/fs05/0311/mcp.asp>

Honeywell (LA), UC-San Diego, and Clemson University have conducted physiological and design testing on gloves and arms. [from the Mars Society Australia page]

Lunar “Coveralls” – An MCP Suitsuit is not enough

There are additional links on the Aussie Marsskin page. As this page does not appear to have been recently updated, we can’t be sure that this research continues. Be that as it may, it isn’t to the point of this article. We think that it is a great start, but for use on the Moon, an outer suit that offers thermal management benefits as well as serving as a first barrier to micrometeorite and sharp rock punctures should be required outerwear in full exposure lunar surface vacuum.

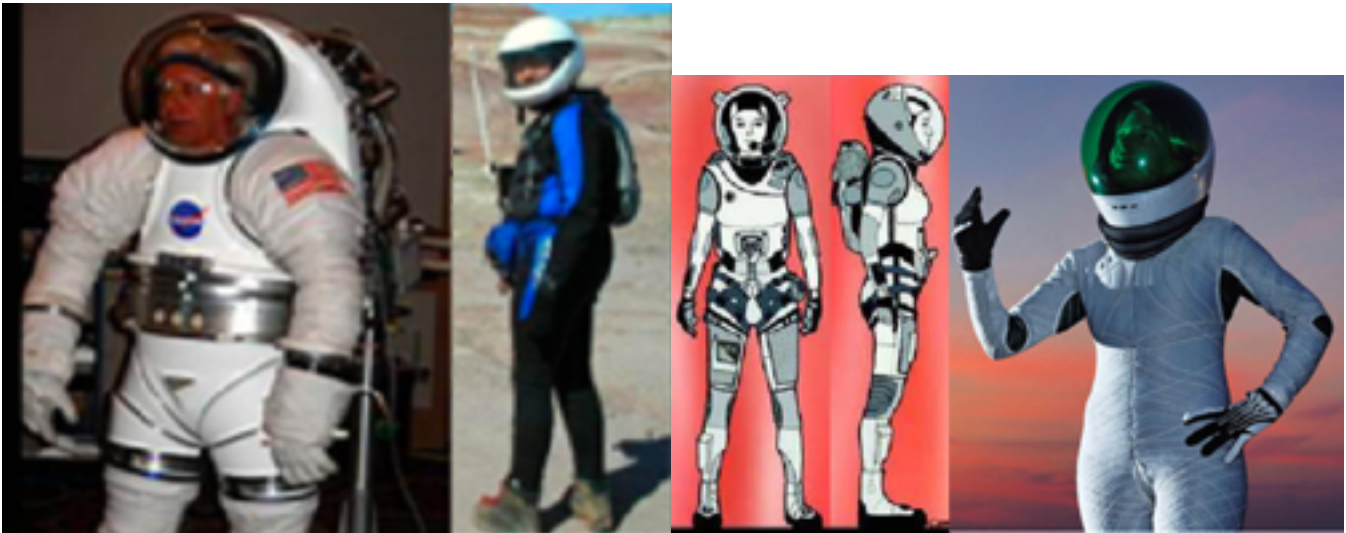
We have talked often about construction of shielded but unpressurized areas for storage of items that need to be accessed on a regular basis, and for equipment needing regular or frequent maintenance. We have dubbed these environments as “lee-vacuum” that is providing “wind” protection. “Wind?” We refer, of course to exposure to the cosmic elements: cosmic rays and solar flare protection as well as micrometeorite “rain.” In such areas lighter weight pressure suits and skinsuits will be adequate, and reduce wearer fatigue as well as greatly improve mobility. Shielding will also deter overheating.

But for wear out on the not-so-protected surface, another layer, which need not also be pressurized, is to be strongly recommended. If this layer is loose, since it does not have to be pressurized, it should not hamper motion as did the Apollo mission suit. Those working on the surface could accomplish more with less effort, and less fatigue, thus reducing risk as well. Such suits might also reduce moon dust buildup on the inner skinsuit. They could also be shed before entering an airlock, and stored outside, thus reducing the migration of dust into interior living and working spaces.

In MMM #225, MAY 2009, pages 6–8, we wrote about “**Skinsuit ‘Outerwear’ for Surface Activities.**”

In this article, we were addressing lee-vacuum environment use, in which one might choose to wear special outerwear, not for any extra protection, but either to hide unflattering body contours, or simply for “fashion fun.”

Here we are talking about heavy-duty outerwear to be worn for protection not adequately offered by skin-suits when worn on the fully exposed lunar surface.



L>R Apollo-like Moon suit > The MCP skinsuit tested by William Fung-Schwarz (MDRS. crew 45 -
 > Counter Pressure suit by 4 Frontiers Corporation > Illustration of the Australian concept

Again, in our opinion, a counter pressure suit, by itself, does not offer sufficient protection in the lunar environment. The Mechanical Counter Pressure suit research is an invaluable and essential first step. But we must mate it with an MCP compatible outer suit.

How much would an unpressurized outer suit resemble the Apollo Moon Suit? It might be about as bulky, and also have elastic wrist and ankle bands to deter moondust contamination of the inner counter-pressure suit. But by virtue of not being inflated, it would hang more naturally on the wearer and greatly reduce joint stiffening (and hence fatigue) that is produced by pressurization. I do not pretend to be able to draw such a suit with my low level of illustration skills.

Has there been experimentation along these lines? I am not aware of any. NASA has supported a number of optional spacesuit design programs in the past, but none are currently funded. And the design features these projects strove to realize were different: they were still pressurized.

It would seem a simple matter for a chapter to get hold of an aviation pressure suit, in lieu of a newer skinsuit, and then design and produce appropriately thick but loose outer suits with elastic sleeve and leg ends, in order to get across these concepts to the public as well as to the space-interest community at large.

If the return to the Moon is undertaken commercially (as well as by non-US national space agencies), it is possible that the commercial firms would be willing to part with tradition and try out and test such new double suit concepts. There is much to be gained both in mobility and in the length of time one could work out on the surface without fatigue.

There is a principle at stake here: if we want our lunar initiative to grow into something permanent, and we do all want that,

We must “do the Moon” on its terms, not ours!

As such a goal is a perfect fit for the Moon Society and for other groups such as the National Space Society - we both want commercial-industrial permanent lunar settlements - promotion of such projects should be pursued. It would be appropriate to provide seed money for modest research/engineering initiatives and demonstrations, if we find individuals or groups, lay or academic, who want to pursue these concepts further

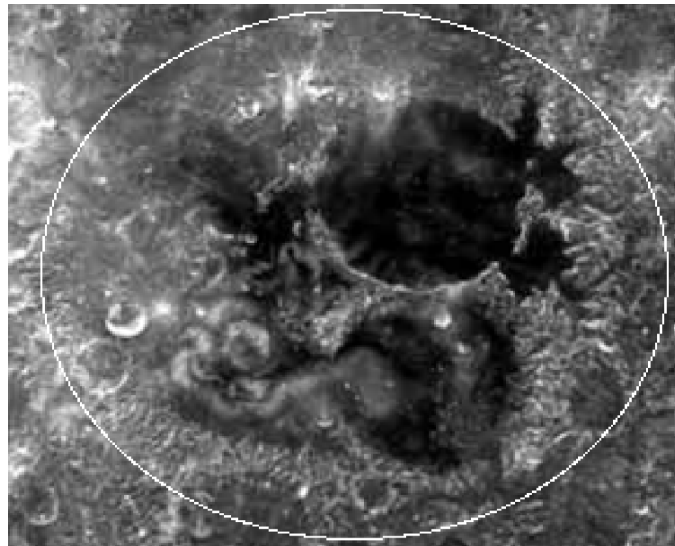
This research is vital!

PK

MMM #240 - November 2010

Mare Ingenii - “Sea of Ingenuity” - A Sweet Spot on the Moon’s Farside

By Peter Kokh



The dark floor crater to the NE is 60 mi wide **Thomson**.
 Can one think of a better place for a very large array radio telescope complex devoted to S.E.T.I.? [Search for Extra Terrestrial Intelligence]

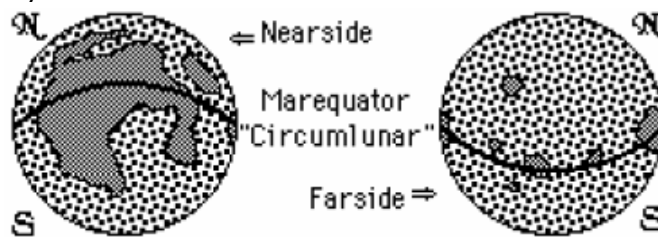
What's so special about Mare Ingenii?

Lunar Prospector detected strong magnetic shields on the farside, at the antipodes of impacts that formed the Mare Imbrium basin centered on Mare Ingenii in south central farside, and the impact that formed the Mare Crisium basin, centered on the crater Gerasimovic in SE farside. What we think happened is at the moment of impact a magnetic plasma was ejected that surrounded the globe coming to a focus at the impact antipodes and permanently magnetizing the surface in those areas.

Such areas may be safer places for surface habitation, requiring less shielding for protection. On the other hand, there is new evidence that these areas also shield against the solar wind, so that the regolith in these areas may be relatively less rich in volatile particles attached to the regolith powder fines.

The "marequator" runs through Mare Ingenii

In MMM # 74, we coined the word marequator: "Some writers have proposed lunar equator-following roads, railroads, and even superconducting cables. The path of least resistance suggests a route that rises north of the equator on the nearside and south of the equator on the nearside to take advantage of the more easily-traversed stretches across the available lava-flow plains."



Unlike the crater Tsiolkovsky, which is another prime site, M. Ingenii is in the central farside slice of the lunar globe that is out-of-line-of-sight from both L4 and L5 Earth-Moon Lagrange positions where the Earth's and the Moon's gravities cancel out, the prime location for lunar communications satellites.
 PK

MMM #241 - December 2010

A Farside S.E.T.I. Radio Telescope Array

By Peter Kokh

In the previous article, we suggested that the deployment of a major array of cutting edge state of the art Radio Telescopes could most easily be done through teleoperation of robotic construction equipment from a perch in the Earth-Moon Lagrange 2 position some 45 thousand miles ~ 65 thousand kilometers above the lunar Farside surface. Such a facility has been the dream of many for several decades. As a boy in my teens in the 1950s, I dreamt of being assigned to such a facility and making a career of it (I have a monastic side).

For most of us, the special appeal of such a location is not for radio astronomy itself, but as the most radio-quiet place within a few light years from which to listen to the “sussuri” – [Latin] “whispers” from the stars, from other intelligent species out there. Yet these days, there is a quite premature discouragement settling in among SETI advocates – those focused on Searching for Extraterrestrial Intelligence, or clear signs thereof.

Why haven't we found any “others” yet?

“We should have heard something by now!” This is a common complaint among the impatient. Yet as the same time, the odds of the existence of other “Earths” out there have never seemed greater. “Nature never does anything once,” I quote. But people forget that Time is as Vast as Space. That a civilization would be found that was not only “nearby” but also “contemporary” with ours is asking to win the cosmic lottery twice in one dice roll.

The difficulty barrier

But there is more to consider. For the most part, we have only been listening, and briefly, with many inter-missions. If every species that wanted to broadcast their existence also did so intermittently and for short periods, it is easy to see how we could have missed their signals. If a race wants to be heard, to be found, it should occur to them that broadcasting must, once begun, continue indefinitely: not for a few days, not for a few years; not for a few centuries. Broadcasting must be a species “cathedral-building” class endeavor, absorbing considerable resources of power and cost. Simply put, it is orders of magnitude easier to listen than to broadcast. The upshot is that it is not unlikely, given the cathedral-building demands cited, that “everyone is listening, no one is sending.”

Whom would a sender want to reach?

I'm not afraid to tell anyone that I am a romantic; it doesn't pay to be anything but. So it is not surprising that I find a universal logic in the Star Trek myth (if you will) about the “Prime Directive.” A superior civilization should avoid contact with inferior ones, as that contact could destroy them, snuffing out their own native inventiveness and originality. Human history is full of examples where contact between unequal civilizations has meant the death of the inferior one. This is ongoing!

It is not likely that there are any inhabited worlds where such unequal cultures have not come into contact. So as a culture matures, it must come to the conclusion that premature contact is not a friendly thing to foist on inferior civilizations, no matter how eager individuals of an inferior civilization may be to skip painful progress on their own, and beam ahead historically through access to advanced technologies.

What is a “primitive” technology?

Well certainly any civilization, which has not come to caring terms with its own environment, must be judged as primitive. Ours certainly qualifies, as those who care about preserving the health of the environment, which nourished us, are still in the minority, effectiveness wise. We still decide things by armed conflict or by financial battles. Face it, as far as we have come, we are very much an adolescent species.

Now it could be that one reason our ventures into space have been so discontinuous, halting, unsure, is that we simply do not have our act together yet. Let's suppose that a mature, environment-conserving species able to resolve all issues by a process that sidestepped conflict and aggression and resulted in widespread consent, wanted to reach out to other species, but only to species at its own state of maturity. How would they filter out signals from getting through to those who were not ready for them?

Well, picking a wavelength that could not pass through a breathable atmosphere (oxygen, water vapor) might be one way. If you sent signals that not only could not be picked up on the surface of a habitable planet, but could not even be picked up where radio-noise from an adolescent civilization was pervasive, then you might have reason for confidence that no one would detect or read your message who was not ready for it.

Not all habitable worlds are going to have moons of size that are rotationally locked, as is our Moon. But perhaps, one could hope, that a civilization mature enough technologically, culturally, envi-

ronmentally, etc. to deploy a radio array on the farside of such a moon, just might be mature. By this argument, it is not at all surprising that we have heard nothing, but that on the other hand, once we are advanced enough to build a major radio array on our Moon's farside, we just might, with a lot of luck, pick up intelligent signals. Now the chances are greater that such signals reach us from far away in space-time, and are not those of a nearby and contemporary civilization.

Recently, we have grown more optimistic that the our galaxy has many millions of solar systems, and that there may be many worlds able to sire intelligent species sooner or later in their history. Top this by adding that the number of galaxies outnumbers the stars within our own. The universe must be full of life, the vast majority of such instances effectively isolated and out of contact with others by the barriers of time and space. For me it is enough to know that there must be others, virtually "everywhere and everywhen," however mutually remote. Here and there will be pairs of civilizations that beat the odds and find themselves neighbors in both space and time. For me, it is enough to look up at the stars and say "Hi," fully confident that all over space and time there are others looking up in wonder and doing the same.

Building first a Radio Array on farside and then finding wavelengths that can go the distance but not be picked up by those not ready for them, and then building a facility to send out messages of our own: "Hi there, we made it! You can too! Life is worth it! May you find all the richness that we have found and continue to find. We go through life apart in space and time, but together in spirit. Peace, love, courage, persistence!"

After many decades of contemplating "SETI" this is where I'm at.

PK

MMM #242 – February 2011

IN FOCUS Telepresence-operated "Robonauts" will revise all "Scenarios"

At first impression, those of us who want to see human frontiers develop "and prosper" on the Moon, Mars, the asteroids and elsewhere in the Solar System may think that the emergence of robonauts threaten that dream. But quite the opposite is likely. These "stand ins" will pave the way at far less expense, We have already integrated "teleoperation" of equipment" into our expectations. Japan and Russia, as well as our own Carnegie-Mellon robotics team, have suggested that site preparation and many construction chores could save substantial amounts of time and money. It costs a lot to put a human on the Moon! Humans are most effectively assigned to chores that cannot be teleoperated. Teleoperated equipment will allow humans to go to the Moon to begin at once to do what only they can do.

Enter the "robonauts" and telepresence! Here the human controller on Earth "sees what the robonaut sees, and feels what the robonaut feels." This is ideal for scientific tasks – for example, where it is not the size, shape or weight of a rock which is of interest, but its chemical-mineralogical makeup." Robonauts can collect samples of special interest thus freeing humans of that tedious chore, so that when they arrive, they can examine a preselected collection, without wasting hours and days in field work.

Roboanuts do not need food, rest or relaxation. They can work around the clock, through a team of tele-presence operators on Earth. They do not get bored. Thus the quality of their work is more likely to be high. As to teleoperated equipment, there will be many chores which cannot be done into their manipulation tools, one of a kind chores, that could not be foreseen, or which will be so uncommon that it would not be cost-effective to further specialize those tools and programs. A robonaut with hands human-like in their degrees of motion, can use hand tools for a limitless list of special tasks. Robonauts can do things to dangerous or risky to be assigned to human crews. In the lead article in this issue we show how these companions can relieve humans of all sorts of risky and tedious chores.

In his article "O'Neil's High Frontier Revisited and Modified" pages 7-8 in this issue, Dave Dietzler shows how the emergence of robotic technologies also radically changes that scenario of how solar power satellites will be produced and deployed. We may not need the extremely expensive Space Settlements, a requirement that could delay the construction of SPS systems by many decades. Humans will still be involved, but in lesser numbers, and with far lower thresholds of support.

To sum up, lunar resources are still a best bet to lower SPS construction and deployment costs, but the cost of accessing those resources will fall by an order of magnitude or more by reducing the amount of human workers involved. Consider that a lunar settlement can begin very small and grow as needed, module by module. In Contrast, a Space Settlement has to be built to a set size, whether it is occupied by a starter crew, or at full capacity. Space Settlements have a built-in high threshold, greatly exacerbated by the insistence on Earth-normal gravity levels.

Now we have previously attempted to remediate these problems in our paper, “**Reinventing Space Oases.**”

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

Just as the cyber-revolution has vastly increased human productivity, so will the robotics revolution. We have nothing to fear!

PK

Role of Robonauts & Robots on the Moon Once Humans have settled in to stay

By Peter Kokh

We have realized for a long time, at least since the early Apollo mission days, that radiation exposure on the Moon from cosmic rays and solar flares was a big problem. The week or so of unprotected vulnerability could be tolerated. But it would be better to provide some sort of shielding for persons intending to stay a while. Two meters of moondust overburden should protect those within habitat modules for stays up to a few months. But long term, 4-5 meters would be better.

We've known this for some time and most moonbase plans have some sort of shielding incorporated as part and parcel of the plan. This need has also made the possibility of locating human installations within lava tubes very appealing. These voids, whole networks of them, are common in the lava flow sheets that filled most large nearside basins, creating the maria (MAH-ri-a, singular MAH ray, mare) or "Seas." But these handy hollows are not to be found at or near either lunar pole, both poles being located in highland areas.

The inspiration out of which the original Moon Miners' Manifesto was born, was that while we had to live "underground", we would not have to live like moles, as Robert A. Heinlein had suggested in his classic novel: "The Moon is a Harsh Mistress," as there were ways we could take the sunshine and views "down under with us."

http://www.moonsociety.org/chapters/milwaukee/mmm/mmm_1.html

But surely we have business out on the naked, radiation-washed surface! We need to explore, to prospect for minerals, to build roads, to trade with other settlements! No people, and surely not the Moon's people, will freely be virtually imprisoned full time. How do we handle this? Read on.

Radiation Exposure Limits and Monitoring

Perhaps every Lunan settler or pioneer or visitor will be required to wear a wristband or other device that monitors one's accumulated radiation exposure. Those whose exposure is under set levels will be allowed to go "outside" - "out-vac" on the exposed, vacuum and radiation-washed surface for limited times, and on limited occasions.

Jobs and Careers

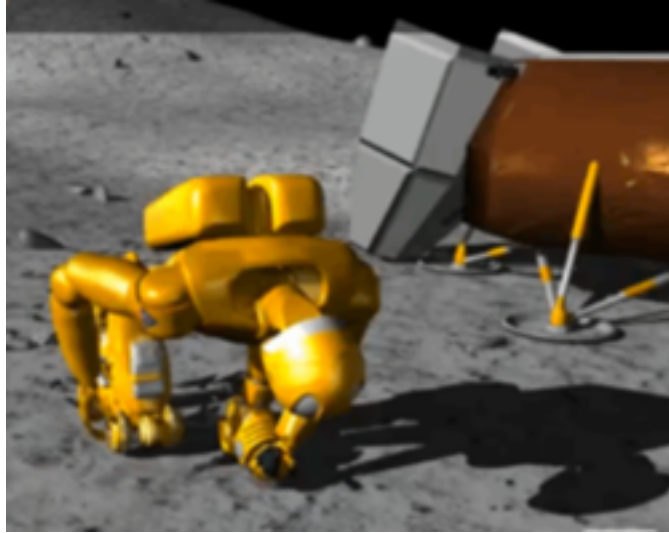
There are those in any population that feel most at home "outdoors" and/or "on the road." But living such a life-style - having such an occupation, could result in radiation sickness and even premature death. Unless!

There are three ways to sidestep this nasty fate.

- (1) Outside jobs could be managed from the safety of shielded habitat spaces, by telepresence operation of robonauts or avatars.
- (2) The cabs of over-the-road trucks, motor coaches, trains and construction equipment could be jacketed by water (somehow kept from freezing or boiling). The jacket need cover only that portion exposed to the sky.
- (3) Outside jobs could be filled by rotation from among a large pool of persons, who would do safe "inside" work most of the time. This would not suit those who wish to be out on the surface regularly, but such types could work in jacketed conditions as described in (2) above.



We might expect to see some out-vac duties preferentially entrusted to robots and telepresence-controlled robonauts that can be put to work “24/7” without fatigue, boredom, and errors, and some to be filled by humans on restricted shifts, but from within the safety of shielded mobile cabs. Routine prospecting, mining, extensive construction, and road-building, are some of the high exposure activities that could be managed this way.



NASA-JSC Project M robonaut: ideal for prospecting and field science controlled from a shielded mobile unit.

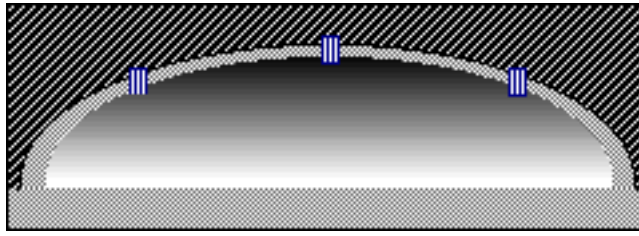
Thus a truck cab could be shielded even if there were no need to shield the cargo containers. How is this different from human workers guiding deep sea well-drilling from the safety and comfort of a pressurized submersible at depths at which human divers could not work? Clearly, those who say we can't work out of our element, have already been proven wrong again and again. Wherever there is something to be gained, we will find a way to conduct our business safely.

Those who rarely travel by train or coach could ride in unshielded units at a bargain price, while businessmen who travel frequently could ride in shielded units at a first class rate. Common sense and a close watch of one's rem-exposure monitors, will allow most pioneers to enjoy an almost natural familiarity with the great lunar out-vac and with its magnificent desolation and spectacular sterile beauty.

Recreation and Sports

In this situation, out-vac leisure activities such as rock collecting, hiking, road rallies, camping out under the stars, and prospecting for the fun of it, would have to be exercised with caution and sparingly. We won't become “Lunans” until we are “at home” on the Moon, and that means “at home” out on the surface as well as in cozy urban burrows. Even so, the availability of a mobile shelter when not actually engaging in the out-vac surface activity in question would make for good policy.

As to sports, the out-vac provides not only one-sixth gravity, but also vacuum, and pioneers will invent interesting and fun sports for such conditions. But here too, there is a way out: pioneers could build a shielded but unpressurized stadium in which low-gravity vacuum sports could be played.



Cross-section of shielded but unpressurized sports arena

Are Demron-layer spacesuits be the answer?

Recently, there have been a flurry of reports that a new polymer fabric offers sufficient radiation protection. But Wikipedia introduces its article with the following warning:

“This article is written like an advertisement. Please help rewrite this article from a neutral point of view. For blatant advertising that would require a fundamental rewrite to become encyclopedic, use `{{db-spam}}` to mark for speedy deletion. (June 2009)”

“**Demron** is a radiation-blocking fabric made by Radiation Shield Technologies. The material is said to have radiation protection similar to lead shielding, while being lightweight and flexible. The composition of Demron is proprietary, but is described as a non-toxic polymer. According to its manufacturer, while Demron shields the wearer from radiation alone, it can be coupled with different protective materials to block chemical and biological threats as well. Demron is roughly three to four times more expensive than a conventional lead apron, but can be treated like a normal fabric for cleaning, storage and disposal. More recent uses for Demron include certified first responder Hazmat suits as well as tactical vests. Demron is proven by the United States Department of Energy to significantly reduce high energy alpha and beta radiation, and reduce low energy gamma radiation. When several sheets of Demron are laminated together the result is a much more powerful shield, though Demron cannot completely block all gamma radiation.”

There is an enormous difference between the kind of radiation hazards found here on Earth such as exposure to radioactive wastes from nuclear power plants and exposure to high-energy cosmic rays coming from all directions of the space or the lunar sky.

In MMM #238 Sept 2010, pp. 4–5, “A Fresh Look at the Spacesuit Concept” ee suggested a two-garment approach: an inner “skinsuit” counterpressure suit, and a loose outer suit to handle thermal exposure and provide puncture proofing. Perhaps a Demron layer incorporated into such an outer suit would allow the wearer to stay out on the surface a longer time before accumulating “x” amount of radiation dosage. But Demron has not been tested in realistic space conditions in Earth-orbit much less beyond the Van Allen Belts. It may or may not help, but certainly won’t be a cure-all.

A lesson some have not learned

At the 2010 International Space Development Conference held in Chicago last May, a speaker confident of what he was saying, crossed off Moon and Mars as future settlement territory on the grounds of surface radiation exposure “unless we wanted to live underground full-time.” Nonsense. If there is one thing the history of the human Diaspora beyond Africa, and even within it, has amply demonstrated, it is that resourceful, ingenious, and determined people can learn to make themselves “at home” and comfortably so, in the most seemingly inhospitable environments. Settlers on Moon and Mars will defy the warnings of such persons, even as have the Eskimo and Inuit of our Arctic regions. “Where there is a will, there’s a way. And we will find ways to survive in environments much more unforgiving and hostile than Moon and Mars.

On frontier after frontier, we have been faced with new climate conditions, new geological and mineral resources, new plant and animal species. Where old tools did not work, or work well, we forged new ones that did. True, some frontiers would not support large populations. But everywhere, people have learned to live happy and productive and fulfilling lives.

Radiation will be a problem for those living and working on the Moon or Mars only until we have learned to deal with it “as if by second nature.” Sure Arctic and Antarctic temperatures can kill! But who would go outdoors in those places without adequate clothing and protection!

Lunan **pioneers** will soon learn what they can and can’t do in their challenging environments. More, they will continue to find new ways to push “this envelope” ever further and further, to the point few would see surface radiation as a game-stopper. Doing the right think, the safe thing, will have be-

come second nature. The pioneers will have become Lunans. And the same transition will occur on Mars and other even more challenging locations.

Take anyone “as they are” off the streets of Mumbai or Cairo and set them down in Antarctica, and we have a problem. But someone from Edmonton or Irkutsk might fare better.

Unlike specialized animal species, humans cannot be defined by their habitat. We are adaptable, and neither the Moon nor Mars defines the limits of that adaptability. We will learn to handle the risks of the lunar surface “as if by second nature” under penalty of death, just as the Inuit have adapted to the Arctic. We will not be at home on the Moon until we do.

To coin a word, we are a **prokalotrophic** species: **we feed on challenges**. And those who warn us that we “can’t” do this or can’t do that, do us all a favor, by spurring us on to prove them quite wrong. And in that sense, science-fiction stories, which can get pretty wild, do us a service. They make us, even if only some of us, confident and determined to spread the human ecumene – the human eco-sphere – beyond the four corners of Earth, beyond the seven continents and the seven seas, to wherever our ingenious heavenly chariots will take us.

The Moon, as a humanized world, will become more interesting and nourishing a life-environment because we have accepted radiation-protection as a challenge. The more formidable the challenge, the sweeter the victory! We would still be in the caves or swinging from the trees if it were not so.

So thanks for the warning. “Bring it on!” PK

MMM #244 – April 2011

Could “Paying Working Tourists” Open the Moon Faster, for Less?

By Peter Kokh

How we’ve done things up to now: who builds what

The cost of doing things in space is undeniably increased by the way hardware (rockets, for example) are contracted out with provisions that highly favor chosen contractors, by decisions motivated by political considerations, of which State or Congressional District will be most benefited, and selection of winners prior to construction and competitive testing.

The switch to real competition between commercial companies should help to reduce costs and improve equipment by a substantial margin. The NASA-Contractor monopoly has had its chance and given us space transportation systems impossible to continue financing.

In the next few years we will see real competition between a variety of crew reentry vehicles and space planes. Some will be best for this use, others for that. And all will be significantly less expensive thanks to real competition.

Crews: the cost of training and support

The NASA Astronaut Corps is rightly held in very high esteem. There will always be some individuals with problems. That’s neither here nor there. But there has been significant criticism of the cost of the program.

An “excess of astronauts — and what they do with their non-flying time — costs the space program far more than money. Their influence throughout the agency contributes to a NASA culture that is artificially enthusiastic, overconfident, contemptuous of outside advice and excessively obedient to short-term goals (as defined by the pilots) — often at the price of sound engineering.”

www.usatoday.com/news/opinion/editorials/2003-07-30-oberg_x.htm

How much does such a system add to the cost of missions to the International Space Station? How much would it have added to now-cancelled Moon Missions? We don’t pretend to know.

But if we are going to switch to commercial providers of hardware, how about also switching to commercial suppliers of trained astronaut crews? We need both, commercial equipment and commercial crews to break out of the amazingly non-American paradigm of “socialized space,” which, as much as we are all proud of NASA, is what it is has been, from day one.

Beyond Commercial Crews

Providers of commercial crews must factor the cost of personnel training, and attrition into the price for their service. While this cost could prove to be a fraction of what it costs NASA to train astronauts and to maintain an oversized astronaut corps, it would seem that there is a way to do even better, in fact,

a way to zero out the cost of crew training and support, so that the cost of a mission reflects only the cost of purchasing competitive space transport systems, and tools and equipment that crews will need.

Zeroing out Crew Training and Service Costs

We are all now familiar with the “Space Tourism Industry.” It began with Space Adventures arranging to bring Dennis Tito to the International Space Station. “Tito joined Soyuz TM-32 on April 28, 2001, spending 7 days, 22 hours, 4 minutes in space and orbiting Earth 128 times.[8] Tito performed several scientific experiments in orbit that he said would be useful for his company and business. Tito paid a reported \$20 million for his trip.” http://en.wikipedia.org/wiki/Dennis_Tito

Tito paid for his training as part of the price for his ticket, and also was required to make himself useful while onboard ISS, and all space “tourists” to ISS since have done likewise.

The “Space Experience Industry”

Right now, we are approaching the dawn of commercial flights to the edge of space. Perhaps it is time to junk the term “Space Tourism” in favor of “Space Experience.” The future of the Space Experience Industry seems to us unlimited. Thanks to John Spencer, the president of The Space Tourism Society, for this term!

Now in the near future where the focus will first be on prolonged zero-g flights to the edge of space, then orbital flights, finally commercial space hotels and resorts, we will be talking primarily about people on “the vacation of a lifetime.” They will do this to enjoy, not to work! Yet crews and staff catering to their needs will also benefit. While flight crews will most certainly be paid as these will be steady occupations, some “staff” – for space hotels, for example – could be paying volunteers, paying a bit less than tourists, for the privilege of staying in space longer, in trade for working assignments. The pay-to-work Paradigm already exists

For some time now, individuals have volunteered, and some even paid, for the privilege of participating in archeological and paleontological “digs.” Something quite similar is common on “Wind-jammer Cruises” where tourist crews man the sails and do other jobs – everyone works, and they do so with enthusiasm for the privilege of a vacation experience otherwise out of reach.

Paying to work in Space

Now most of us need to “get paid” for work, and are hardly in a position to “pay for the privilege of working.” But make no mistake. Those who pay to work do get paid! Their pay is an unforgettable experience! Yes, of course, this is an option available only to those with enough income or resources to pay for the privilege. That this is not an option open to most of us is quite irrelevant. The point is that there is a population class growing in size that has begun fueling a “pay-to-work” sector of the economy that is growing year by year.

Fast forward a bit: we foresee the emergence of commercial companies that supply personnel who have paid for their own training, and who are ready to pay for the privilege of using that training on actual assignments – in space. Some will staff budget space hotels and resorts. And beyond that?

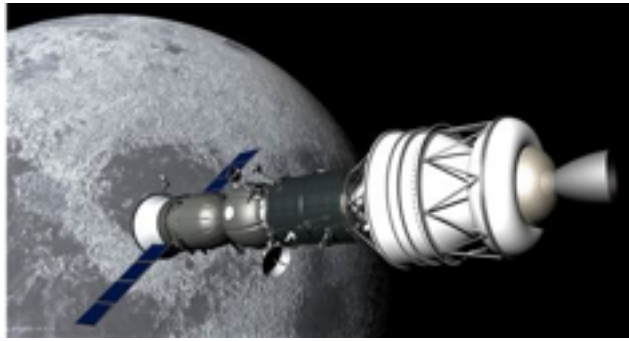
Space Adventures’ 1st Private Moon Expedition

“Make history as the world's first private lunar explorer.

“Witness Earth rise as you emerge from the far side of the moon.

“Become a catalyst for humankind's expansion into space.”

“Space Adventures invites you to join us for the most significant private expedition of our time – launching the first private mission to circumnavigate the moon.”



Space Adventures, working with Russian providers of the vehicle and service module needed, has already signed up one of the two tourists, who, with a Russian astronaut pilot, will make the first commercial Apollo 13 type loop-the-Moon trip. (Apollo 8 made several orbits about the Moon before returning.) A second customer is said to be ready to sign. **Watch this Space Adventures Video:**

http://www.spaceadventures.com/videos/LunarMission_no_ZG_msg_300kbps_480x270.mov

This flight could occur within the next to years, and will be the first presence of humans near the Moon in forty years, many years before any national space agency.

What next for the Space Experience Industry?

Once this flight is history, or perhaps even before out of anticipation, there will be a growing interest and demand among “experience-seekers” willing to pay the price for lunar landing excursions. Now there will be no on site facilities to cater to them. So what would be the cheapest way to provide such facilities? You got it! The ideal site for an ever-growing tourist complex having been identified in advance, the first paying experience seekers will plot out the site, photograph the site in detail and do additional investigation to supply architects on Earth with the information they need to draw up plans for the first structures, and a game plan for additional expansion. Perhaps this first crew could also leave a robonaut behind to be telepresence-operated by persons back on Earth to continue making site improvements in advance of the arrival of a second private crew again paying not only for their own training, but for the privilege of working on arrival at the selected site.

For an ideal site location idea, read “An ‘All-in-One’ Moon Resort” pp. 82–85, **MMM Classic Themes – Lunar Tourism**, a free download at:

http://www.moonsociety.org/publications/mmm_themes/mmmt_tourism.pdf

Because “pay for the experience” tourists will be taking on serious work assignments, and have even paid for the training to allow them to do so, their tickets to the Moon (resort) will be cheaper than those of purely passive tourists. Those willing and able will pay-to-prepare, pay-to-build, pay-to-explore, pay-to-prospect, and pay-to-deliver services.

Yes, these people will come from the wealthy, as few of the rest of us will be able to compete for these positions. But the point is that in this manner, lunar surface facilities including not just tourist resorts but science outposts, even initial factories, will get built sooner and at far less taxpayer expense (translate that to freedom from political veto power).

As we have suggested, pay-for-experience tourists will be accompanied by and work with robonauts who will do the boring, repetitive, and dangerous tasks. They need no life support, no rest or recreation, and no need to return to Earth. They also require less room aboard the craft that bring pay-to-work tourists to the Moon. Thus robonauts promise to greatly multiply the cost-effectiveness of this approach, and bring down all costs even more. So we can add to the “pay-to” list, pay to teleoperate, and pay to maintain equipment.

This scheme can serve to expand science on the Moon as well as tourism. “Pay-to” personnel can also go to the Moon for the privilege of collecting specimens, of prospecting, and doing all sorts of scientific research. They can also pay for the privilege of testing equipment to turn moondust into usable materials – “ISRU” – “in situ” [on location for those of you not familiar with Latin] resource utilization. Thus people may “pay-to” develop building materials with which to expand habitat and outpost complexes with far less “upports” from Earth.

We do not pretend that this scenario is certain to develop. The World Economy is too near implosion, and that could put off all plans, commercial as well as tax-supported inefficient government programs.

Wikipedia "**Extreme tourism** or **shock tourism** is a type of niche tourism involving travel to dangerous places (mountains, jungles, deserts, caves, etc.) or participation in dangerous events. Extreme tourism overlaps with extreme sport. The two share the main attraction, "adrenaline rush" caused by an element of risk,"

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

Yes, there will be space tourists in the traditional sense who want to just enjoy and sightsee and they will pay even more to go into space. But here we talk about those who will pave the way and create places for others to visit. Here we talk about space tourists willing to pay for own training, pay their own insurance etc.; who pay (rather than get paid) for work and assignments.

How do we cover cost of equipment, vehicles, etc.? A first answer would be the commercial companies and consortia who want to operate lunar resorts, and deploy factories on the Moon, mining operations etc. Keep in mind that this is an introductory article aimed at getting further brainstorming in high gear. We offer this article as a contribution to a **Commercial Model for settling the Moon**.

Addenda: Opening the Moon to the less-well-to-do

The overwhelming majority of us would never have the resources to participate in such a scenario. But there could be **lotteries**, with drawings to be held when the combined entry fees exceed the costs to be covered. Winners who did not pass medical and other tests, could sell their rights to the highest bidder. But there could also be limits on those who could enter, to minimize such situations.

When Weight is an Issue

One thing we have not discussed is the simple hard fact that transporting anywhere in space those who are bigger and heavier goes up in proportion. Should otherwise capable midgets, dwarfs, and just smaller individuals pay less? For passage perhaps, but maybe not for training.

We hope you enjoyed this article and that it sets off a chain of constructive brainstorming.

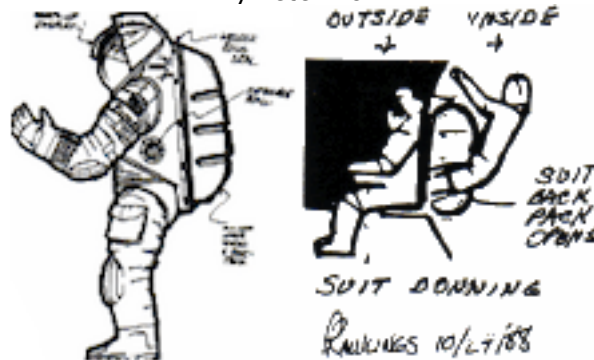
See you on the Moon!

PK

MMM #246 – June 2011

Turtle-back Spacesuits & Suitlocks - Recent NASA Experiments

By Peter Kokh



VIDEO: <http://www.wimp.com/lunarover/> The suit demonstration is 6–7 min. into 10.3 min. video

Foreword: NASA is now working to engineer a concept that seems to have originated with Pat Rawlings way back in 1988, and about which we have written several times since then: a minimal air-lock of which the spacesuit itself is an integral part. We got the idea from a 1988 sketch Pat Rawlings did for the then upcoming made-for-TV science fiction movie "Plymouth" aired May 29, 1991. The concept did not make it into this movie itself, however.

From Past Issues of MMM

MMM #89, October 1995 "**Dust Control: Engineering Counter-measures – Suit-Locks**" – reprinted in MMM Classics #9 pp, 43–44

MMM #151 December 2001, p 3. "**Engaging the Surface with MOON SUITS instead of Spacesuits**–reprinted in MMM Classics #16 pp. 2–4

<http://www.moonsociety.org/images/changing/turtlebacksuit.gif>

“The idea behind this ‘turtleback’ or ‘clamshell’ suit is to avoid tracking moon dust into interior spaces without the expense of sizable and complex ‘carwash’ airlocks. Ideally, the back of such a suit would include the back of the helmet as well. The wearer would back in to a conformally shaped dock, with the suit locking to it. The dock and the suit back would open together into the habitat space, and the wearer would reach up inside to a grab bar and pull him/herself out of the suit. The dock would close and the suit taken away for storage outside as in a dry cleaner rack. Very little inside air would escape in a very tight cycle process.”

The whole idea is to conserve interior air by prevent wholesale exhausting into the exterior vacuum by the repeated cycling of airlocks. Not only do we need to conserve oxygen, though it is abundant on the Moon locked into the various minerals in moon dust, but even more importantly, the nitrogen component: Nitrogen, of all the major elements needed to support life, is the least abundant on the Moon, present only as a solar wind component. In contrast to “turtle-back” suit-locks, inefficient airlocks would be more expensive to produce, and take up a lot more space. This last point is critical for vehicles from which egress to the surface is provided.

Differences in Rawlings/MASA version from our earlier suggestion

You will notice that in the Rawlings’ version, the suitback does not include the back of the helmet; nor does NASA’s new experimental version. We personally think that this makes ingress and egress from the suit more of an acrobatic chore. The advantage is that the wearer can turn his/her helmet side to side, up and down. But with a wrap-around panoramic visor, the wearer’s head could turn and tilt freely inside if the helmet was rigid, its back a part of the rigid suit-back. But to see this concept finally taken seriously by NASA is very encouraging. It is a sea-change in suit design that is long overdue.

Stills from the video, showing step by step process:



1: two empty suits ride on back of rover



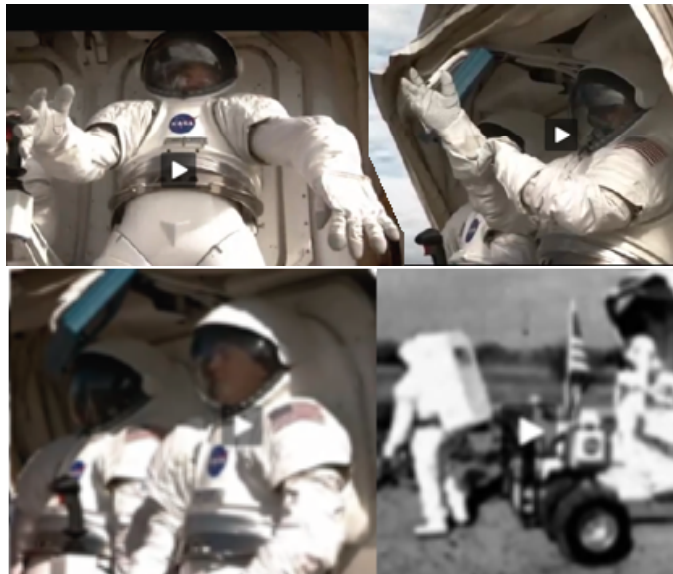
2: Inside suit-lock entrance at left, climbing in at right



3. From outside, astronaut getting into suit at right close, closes



5. Suit back has closed, suitlock begins to close, closes



4. Astronaut extending arms into suit sleeves & gloves 6. Astronaut ready to leave porch on foot right
The future of Space-suit design

Previous NASA manned rover research has been concentrated on unpressurized vehicles. But the clear need for more capable pressurized vehicles has forced major rethinking of air-lock concepts. To include the much larger “car-wash” type airlocks that included “de-dusting” operations and suit-storage, would greatly increase the size and cost of surface vehicles.

We predict that as these new suit-lock concepts are perfected, suitlocks will become the obvious choice for fixed moon bases and outposts as well. The plusses overwhelm the minuses:

- **vastly more compact**
- **conserves oxygen**
- **conserves nitrogen**
- **greatly reduces import of moon dust in habitat and vehicle interiors**
- **greatly reduces size and mass and cost of vehicles**
- **requires standard backpack, while allowing personally tailored suits**

NASA’s switch to this concept will instantly date all past depictions in art and film of what operations on the Moon and Mars will be like. PK

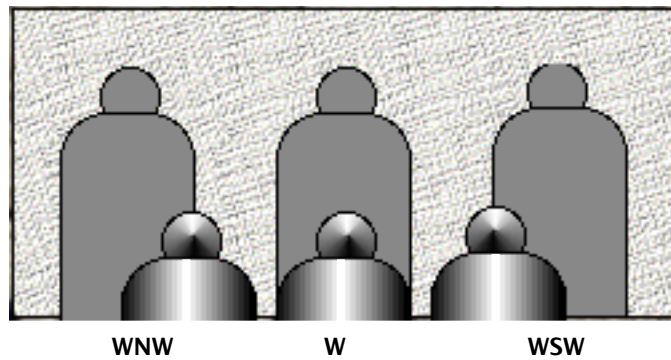
How to go for a nice Walk on the Moon, and not get lost!

By Peter Kokh, Wisconsin Northwoodsman

May 17, 2011 outside Florence, WI - This morning my 9-year old “alley” shepherd (va)Nessa and I went for a long walk along a dead end country road, facing east towards the sun, but then returning walking westbound through the woods north of the road. While we were walking back through the woods (Spring is best, before the trees are too leafed out, or Fall, after the leaves have fallen, so that the sun gets through), it occurred to me that my Northwoods instincts might work on the Moon.

**Always keep the sun to your back, and follow your shadow.
 You won’t get lost or go far astray!**

Now on the Moon, the “Dayspan” is 14 and 3/4 of our 24-hour Earth days long. So my advice is to pick a destination towards the west (WSW-W-WNW) for an early “morning” walk (1-4 days after sunrise) and towards the east (ESE-E-ENE) for a late afternoon hike (1-4 days before sunset)



Now to return, if you don't want to wait a week or more until the Sun-angle is just right for following your shadow, you can follow your footprint trail – if – and this is a very big “if,” you walked through “virgin” territory, and there are no other boot-prints but yours. But that's risky, as someone may have crossed your path since you made it, and then you could get confused. It is better to wait to follow your own shadow!

Dress for comfort

Don't wear a NASA-Apollo suit designed for maximum fatigue in the minimum amount of time. The traditional “spacesuit” combines two separable functions in one garment: (1) maintaining breathable air pressure, (2) protecting from thermal extremes and punctures from sharp rocks and from the constant dust-particle size micrometeorite rain. Instead, a **mechanical counter-pressure “skinsuit”** will allow you to breathe and yet move your arms and legs much more freely. Then don a **loose outer suit** with the same layers as an Apollo suit, to provide the needed puncture resistance without encumbering motion and tiring you out prematurely. Then with water and air supply, you should be able to walk at ease for many hours, thoroughly enjoying your sense of freedom during your walk on the Moon, “as if you were at home on Earth.” What an achievement!

[See **MMM # 238** Sept 2010, pp. 4-5 “**A Fresh Look at the Spacesuit Concept**”] [Reprinted above]

Now as to bringing your dog along, in an equally comfortable 2-part suit, he or she might get frustrated, as bending down to sniff rocks but unable to sense any odor will disappoint and confuse them. And for a male, trying to lift a leg and mark his territory will only make one leg of his suit very, warm and wet. Maybe in time he would stop trying. Maybe a custom-made fitted urinal bag? Hmmm! I smell a lunar patent!

Yes, there are many areas of the Moon that are very boring, especially out on the maria (Tranquility Base) but areas in the highlands or along highland-mare coasts, or along rilles and scarps could be pleasantly scenic. And just knowing that you are the very first human to pass that way could be especially rewarding (look, ma, no bootprints but mine!) Not all humans enjoy a quiet walk in a nature setting all alone, communing with nature, with themselves, while deep in thought. But perhaps you are one of those like me, for whom there is a special bond with the raw outdoors and nature, best enjoyed alone, even though we may want to share this experience with another on a return trip! **PK**

MMM #259 – October 2011

Lunar Toll Roads – Taming the Magnificent Desolation of the “Out-Vac”

By Peter Kokh

In the pages of MMM, we try to illustrate what is possible and feasible on the Moon, in time. It is important to envision ways in which the Lunar Pioneers will gradually make themselves at home on a dead, dusty, radiation-washed world. Yes, it is also important to illustrate the type of baby steps by which we will establish a “beachhead.” But to really motivate ourselves and the actual pioneers who will be inspired to take on the awesome challenges of living on the Moon, we try to show “how we are going to make the Moon a great place to live bit by bit.”

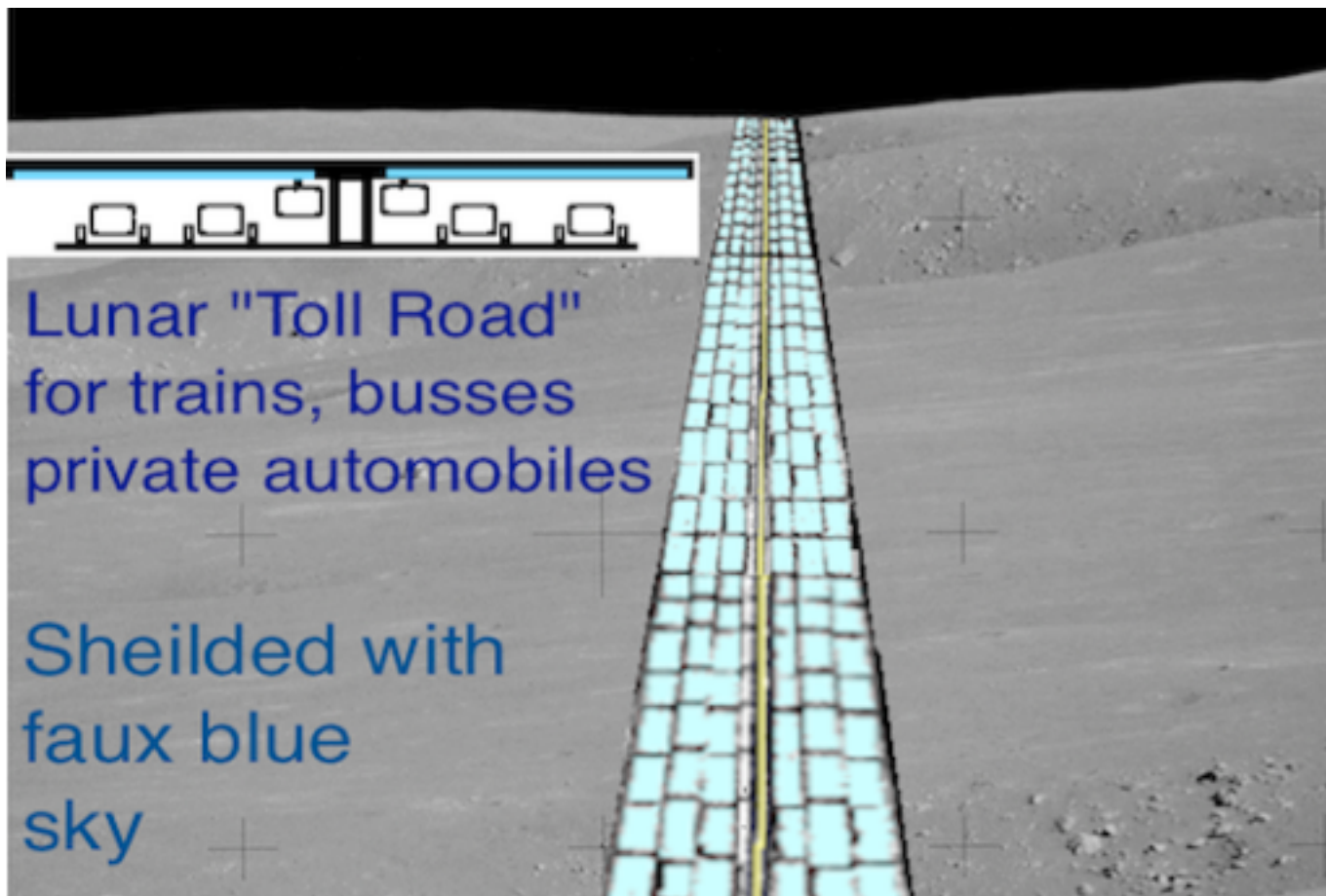
Our first roads will be graded and compacted moondust, a row of the removed boulders probably between the two opposite-direction lanes. Early vehicles, without shielding, will be used sparingly by individuals, who may be limited in their allotted time per month out on the exposed surface.

Now fast forward a few decades. We have a thriving frontier world with multiple growing settlements large enough to be called cities. If there are two such, in close enough proximity to generate real “traffic”, and whose complementary economies support frequent passenger travel and cargo shipments back and forth, why could we not design and build a “toll road” that makes travel, even frequent travel, rather safe.

First envision a canopy, a bit wider than the roadway underneath, supported on pillars down the middle and here and there along the edges. The canopy is covered with 6 foot or 2 meters of moon-dust. Travelers will still be exposed to some radiation coming in parallel to the surface along the sides, but this will be a small fraction of the amount of radiation they would receive without the canopy.

Now envision the underside of the canopy a bright sky blue, uplit by sulfur lamps in the base of the pillars. The “black sky blues” will be banished for the duration of the ride.

From the canopy towards the center on either side, will be a suspended monorail. Below, two lanes on either side for trucks, motor coaches, and private vehicles. Add even more hospitable “way-sides” at junctions.



Toll Road image by Dan Moynahan, extended by Peter Kokh – road cross-section by Peter Kokh

For high traffic corridors between settlements, here is one way that brings together experiences on old Earth and life on the desolate but magnificent landscapes of The Moon. The advantage over a tunnel is that travellers get to see the moonscapes to each side.

Granted, pioneers are not going to see something like this until there are a number of substantial settlements with economies that generate traffic between them. But it will come.

The chances of a meteorite causing significant damage are slim, but not zero.

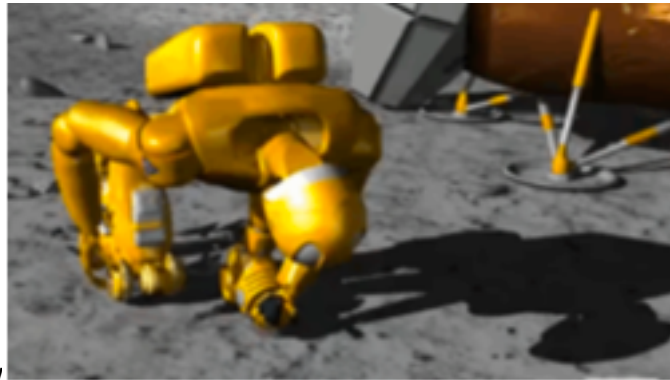
Comments and suggestions always welcome. ###

“Telepresence” Tours of the Moon: How Soon?

By Peter Kokh

Scenario: It is July 20, 2019, the 50th Anniversary of the Apollo 11 Moon Landing by Armstrong and Aldrin, and NASA is celebrating big style. At all eight NASA centers around the country, new Moon Telepresence Centers will open up. At each center, you can make reservations for use of a Moon Telepresence Booth, by the quarter hour.

Inside the booth, you are helped to get into a telepresence outfit which includes moon-visors, special moon gloves, and and moon-shoes. On the Moon, at the Apollo 11 site or a number of other interesting sites, “avatars” will walk, bend over and pick up rocks, and look at them, or just scan the horizon, as you wish. You will have all the sensations of being there yourself, except that you will still have your Earth-weight (Oh shucks!)



How

soon?

Telepresence equipment is advancing by leaps and bounds, and the six and a half year window may just be enough. Now NASA and a number of commercial firms specializing in robotics are not pushing this technology for you the visitor, but for the sake of science and exploration. For most of the involved parties, the incentive is not public use. But for some, it may be. Indeed some of the breakthroughs needed may be motivated by potential profits from such tele-tourism markets. That’s the process of “spin-up” that we had described way back in 1989. Read:

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

This development path is just the opposite of “spin-off.” Instead of NASA embarking on a crash research program at exorbitant cost and then turning over the resultant technology at no cost to commercial enterprises with the taxpayer footing the bill, in “spin-up,” a private enterprise, seeking profits, develops the technology, with the consumer paying the bill. As a result, when the technology is needed on the space frontier, it is already “on-the-shelf” and in need of relatively inexpensive adaptation only.

In a recent article in Space Review(online), there just such a possibility is discussed:

“Is there a way for humans to be on a surface of another planet without actually physically being there? Dan Lester argues that, thanks to the increasing capabilities of robotics and related technologies, telepresence can be the next best thing to actually being there, at considerably less cost and risk.” <http://www.thespacereview.com/article/2150/1>

So what?

For billions of people who cannot afford a multimillion dollar “loop the Moon” tour, this will be a much less expensive opportunity, not to skim over the Moon’s surface at an altitude of 5–100 miles, but to have all the experience and sensation (less the lighter gravity) of walking on the Moon, picking up and feeling a moon rock, and doing a little exploring. Each option will offer different “unforgettable” experiences. This is important because as more and more people take such a telepresence Moon tour, and tell their friends about it, the more public interest in supporting permanent outposts, then tourist centers, on the Moon itself will grow.

The catch is less in developing the “avatars” through which you will see and feel yourself on the Moon, than in sending enough avatars to the Moon to meet telepresence demand, and in their maintenance. The first such experiences will be expensive. But the cost will come down as demand increases.

What about Mars?

The reaction time delay for command and response in telepresence on the Moon is of the order of three seconds, the time it takes for command signals to get to the Moon, and perceived command execution at the speed of light. For Mars, the delay will be from a 6 to as much as 40 minutes – it is just not practical.

When will lunar telepresence tours come to a NASA Visitors Center near me? The timeline suggested above seems realistic, especially if commercial firms take the lead in the “spin-up” process described. If it is left up to NASA, it becomes a budget item, which we all know will always be at high-risk for cancellation at any stage of the process. In the meantime, do watch this video:

<http://www.youtube.com/watch?v=kFPNcWN7QnM> MMM

MMM #264 – April 2012

Revisiting the “Snuglining” & “Snuglocks” Concepts

By Peter Kokh

In MMM #79 October 1994, in an article entitled “Vehicle Design Constraints,” in a section entitled “Saving Atmospheric Gases: “Snuglocks” we wrote”

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

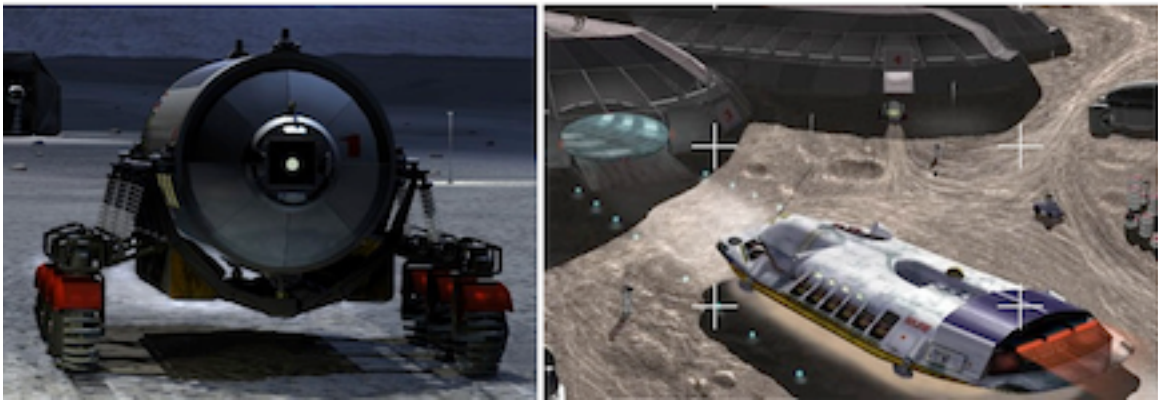
More importantly, however, at least in its immediate economic ramifications, is the principally exotic, or Earth-sourced nature of the Nitrogen we will need as an atmospheric buffer gas, one with biospheric importance as well. In short we need to conserve both oxygen and nitrogen. One way to do this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

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

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

Previously, in another article “**Harbor & Town**” MMM #56 June 1992 I wrote: “Detachable holds of trade vessels making circuit rounds between various settlements might be designed “snugline” fashion to slip into special airlocks and taxied or tugged to an in-city market berth where they could unfold for business,”

On target illustrations by noted space artist Pat Rawlings



Left: S173 – here we have a cylindrical vehicle with a detachable chassis

Right: S245 – we see an open “oval” “snuglock with an oval hull and detachable chassis

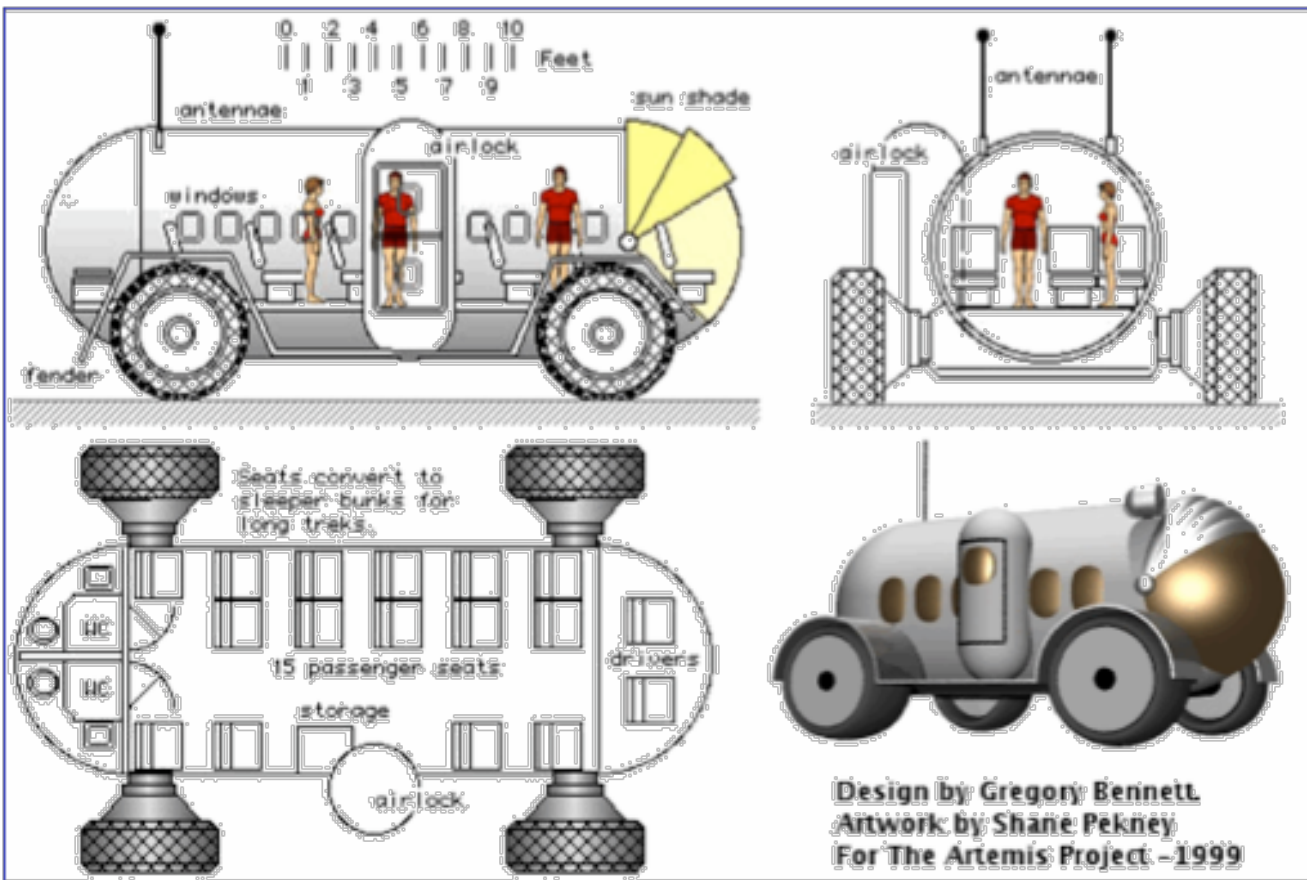
The advantage is that properly designed, vehicles in a short list of cross-sections, can slip in and out of such holds without their road chasses and with a minimum of air (oxygen and even more precious nitrogen) being exhausted into the vacuum. Obviously, this is a concept that needs to be more fully developed. In the process a short-list of vehicle minus chassis should be designed.

Voiding moist oxygen in either personal airlocks or vehicle locks, wastes precious water and will eventually give a rusty hue to the surroundings, a tell-tale sign of waste. As to Nitrogen, of all the gases essential to life, Nitrogen is the one in shortest supply on the Moon, to the point that we may do well to use a less Nitrogen-rich air mix. That is something easily tested on Earth, or in the International Space Station. Otherwise, nitrogen, not water, could be the element that put limits on population growth as well as on open spaces and high ceilings.

This concept complements the turtle-back suit and suit-lock concept. See the MMM Glossary <http://www.moonsociety.org/publications/m3glossary.html> Entry: "Turtle-back" Spacesuit Airlock –

PK





Visitors to the Moon will enjoy tours of the Artemis Project facilities aboard these pressurized tour buses.

Read "An "All-In-One" Moon Resort" - MMM #136 - June 2000 Above

First sun (odd # sunths)							Second sun (even # sunths)								
A	C	E	Mo	Me	S	T	P	A	C	E	Mo	Me	S	T	P
1	2	3	4	5	6	7		1	2	3	4	5	6	7	
8	9	10	11	12	13	14	15	8	9	10	11	12	13	14	15
16	17	18	19	20	21	22		16	17	18	19	20	21	22	
23	24	25	26	27	28	29		23	24	25	26	27	28	29	30

LEFT - As Dayspan/Nightspan lighting conditions would repeat each two "sunths", a never-changing 2-sunth Calendar sheet or plaque would do.

Reconciling the 24 hour day with the 708 hour long Sunth (lunar dawn to dawn = Dayspan/Nightspan Cycle) - will be easy. Lunars would simply alternate sunths of 29 + 30 days, adding a leap hour every 7 weeks or so for a longer night's sleep.

If settlers adopted a variable length week, five 7-day weeks with three interspersed 8-day weeks makes 59 days or two calendar sunths exactly. That would put local sunrise and sunset regularly not only on the same date, but also on the same day of the week.

Below: Surface Activities of the Humorous Kind

HARVEST MOON

by Andy Weber



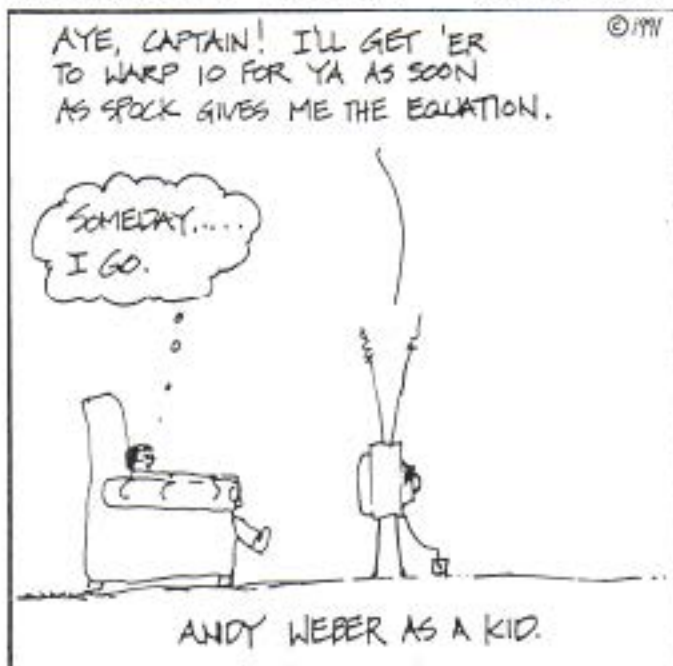
HARVEST MOON

by Andy Weber



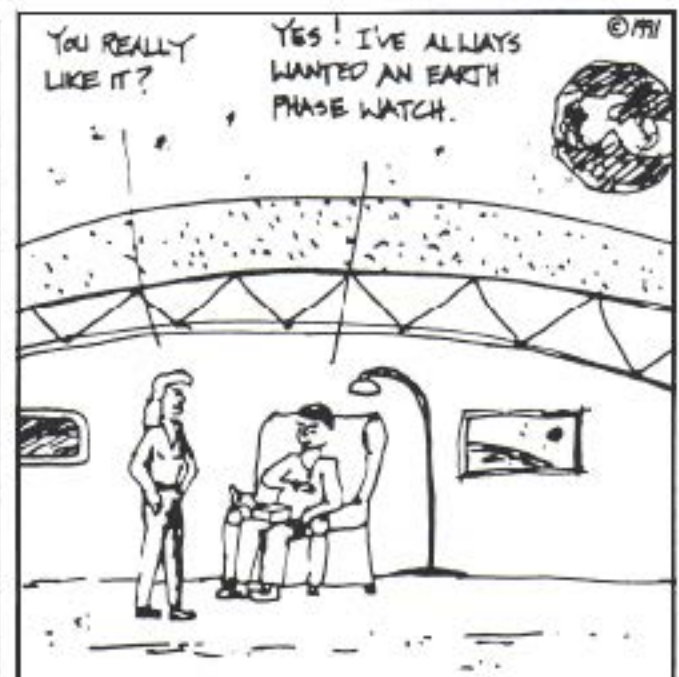
HARVEST MOON

by Andy Weber



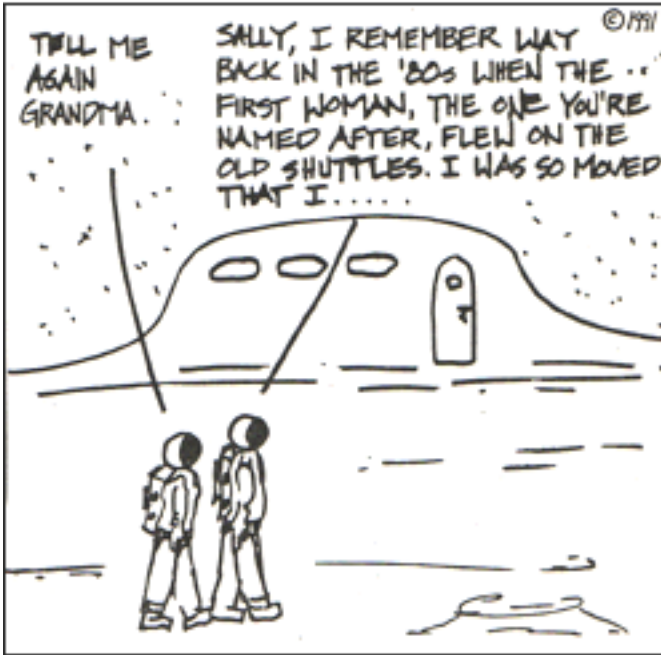
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No grimmer fate can be imagined than that of humans, possessed of godlike powers, confined to one single fragile world. -- Kraft Eरिके

"Homo Lunensis"

"We must develop the habit of dealing with anything and everything lunar in such a way that the Moon becomes a place where we will have learned to become truly native."

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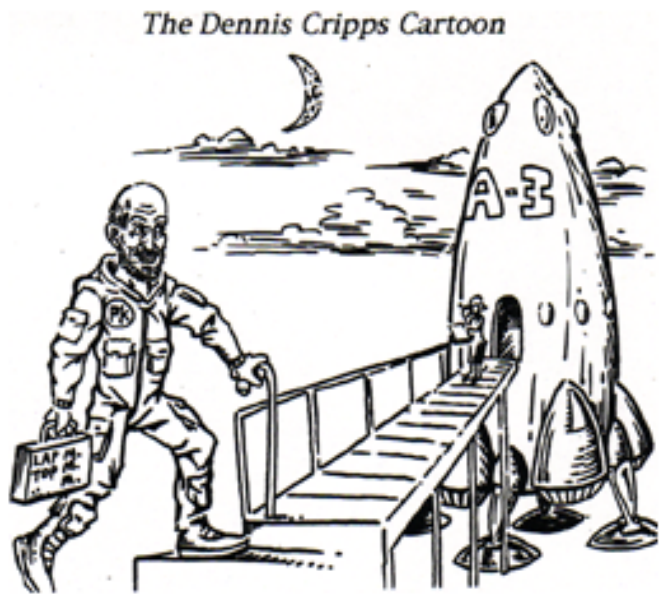
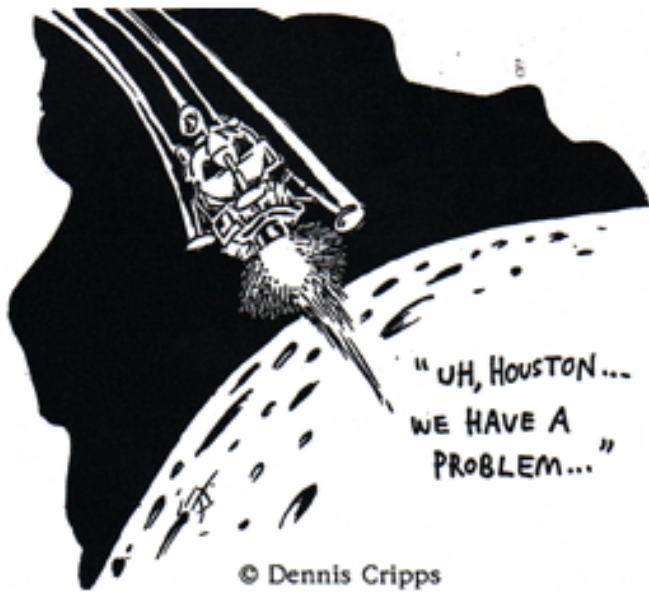
Firstsun (odd # sunths)							Secondsun (even # sunths)								
A	C	E	Mo	Me	S	T	P	A	C	E	Mo	Me	S	T	P
1	2	3	4	5	6	7		1	2	3	4	5	6	7	
8	9	10	11	12	13	14	15	8	9	10	11	12	13	14	15
16	17	18	19	20	21	22		16	17	18	19	20	21	22	
23	24	25	26	27	28	29		23	24	25	26	27	28	29	30

LEFT - As Dayspan/Nightspan lighting conditions would repeat each two "sunths", a never-changing 2-sunth Calendar sheet or plaque would do.

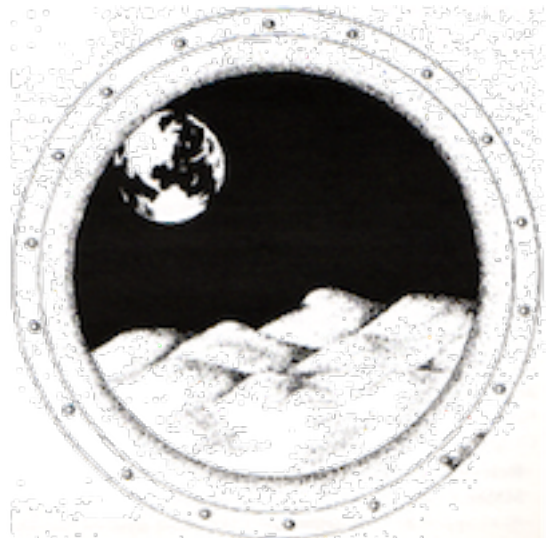
Reconciling the 24 hour day with the 708 hour long Sunth (lunar dawn to dawn - Dayspan/Nightspan Cycle) - will be easy. Lunans would simply alternate sunths of 29 + 30 days, adding a leap hour every 7 weeks or so for a longer night's sleep.

If settlers adopted a variable length week, five 7-day weeks with **three interspersed 8-day weeks** makes 59 days or two calendar sunths exactly. That would put **local sunrise and sunset** regularly not only on the same date, but also on the same day of the week.





The Lunar surface is sure to have some effect on the spirituality of future settlers



See you there!