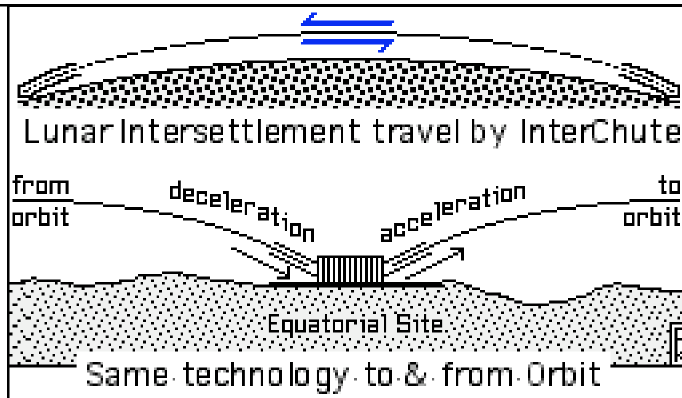
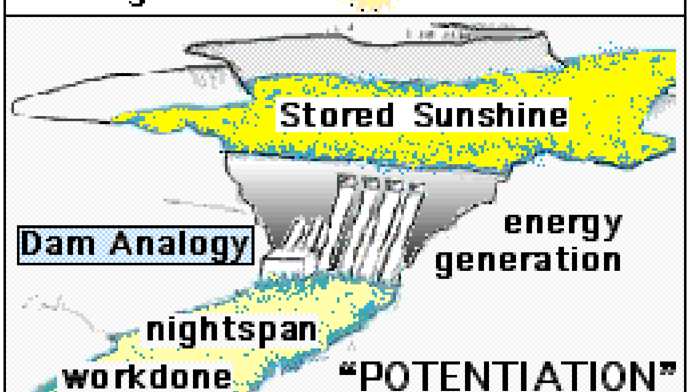
MMM Classics | **Year 13: MMM #s121-130**
The First Fifteen Years | December 1998 - November 1999

During our 13th year, we tackled several challenges to lunar settlement. First, the Moon has no atmosphere and that means people will not be able to get around on airplanes. But if we have man-rated (low acceleration) mass drivers, they could be run in reverse as mass catchers. We could lob crew cabins into space, and catch them as well without the need for retrorockets. If we can do that, then we can use the same equipment to lob "coach cans" on suborbital hops to distant parts of the Moon.

But a more immediate challenge is the boogeyman that prompts otherwise respectable "experts" to seek refuge at the so-called eternal sunshine areas of the poles, distant from where lunar industry must locate. We need to do as winter-hardy animals do, squirrel away extra dayspan sunlight to put through various kinds of processes to produce live nightspan power. What we need most is simply ingenuity and creativity . The sunlight is there, waiting to be dammed up - "Potentiation."

Providing shielding to provide protection from the various cosmic elements is another very pragmatic topic. In "Shielding: the B Options," we look at the many ways we can use regolith to protect modules of various designs. Some will have special advantages .





Some pioneers may want to return to Earth periodically and it will be prudent for them to maintain "Hexapotency", maintaining muscle tone able to handle gravity six times "lunar normal." There will be various means they can use.

When it comes time to expand the settlement population in an "inflationary" fast manner, it may be cost and time-effective to mass produce habitats of a limited variety of designs. Much as did those who settled in a "Levittown," the proud owners will quickly find ways to customize them as expressions of their own individuality, tastes and needs.

We've talked many times about the Moon's "hidden valleys," intact lavatubes of generous proportions. We look at Oregon L5 proposed "Radar Flashbulb Project" that might be able to map these features.

Being caught "neatly" by a mass driver run in reverse is one way to do without landing fuel. Charles Radley offers his Dragger concept for saving retrorocket fuel.

As the settlement(s) grow, so will the need for "Home Rule" and we take a look at all that this will imply.

Earth-gazing "out the window" will be popular enough to give rise to some neat electronic "Earth browser screens" and similar divices.

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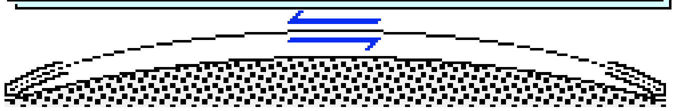


No air = No airplanes = No airports !

We *can't* fly around the Moon! Perhaps - *yet maybe!*

The **"Interchute"** uses a fixed pair of mass driver/ catchers to fling passenger "coach cans" back & forth between pairs of settlements where traffic warrants. See below.

In Focus ▣ *Required Beyond Mars - "Cryosynthetic Materials"*

Commentary by Peter Kokh

With the growing crescendo of interest in Galileo's ongoing flyby probings of the ice-crusted ocean moon, Europa, NASA and others are already brainstorming Europa orbiters and ice-crust penetrators. Suddenly human horizons have expanded well beyond Mars. Whether we find Europa fertile with primitive life forms, or barren but ready for fertilization, the prospect for human expeditions out to Jupiter's realm looms strong. It is a challenge that we cannot now meet with present technologies, no matter that several movies have depicted such exploits, notably Arthur C. Clarke's 2001 and 2010.

Already we realize that chemical rockets are marginal for Mars. They *will* get us there and back, but with barely acceptable long flight times to and from, exposed to cosmic rays and solar flares. Continued Mars exploration and outpost support will require faster fleets of nuclear powered ships.

Nor does the prospect of spending so much time in zero-G *only to arrive too weak to explore or work* make sense. The engineering problems of artificial gravity may scare NASA into a conspiracy of silence on the topic, but *the bullet must be bit*. We have to start experimenting with artificial gravity spacecraft architectures, *off the drawing boards!* On past Mars to Jupiter's moons, and to Saturn's, these technologies are *absolutely essential*.

As we go further out, we will encounter a quite opposite materials-availability situation from that which challenges us on the Moon. Instead of the volatile-impoverished regolith soils, we will more and more be finding metal- and silicate- (rock) poor volatile-rich icy crusts. Where in the inner system, ice-rich asteroids and comet-hulks will be the prize, in the outer system, bodies, large or small, with economically mineable deposits of rocky materials will be the prime target of the claim-stakers.

As a hedge, we should be experimenting with synthetic materials processable from outer system-rich water-ice and abundant carbon and nitrogen compounds to make "cryo-plastics" that will not be unserviceably brittle in the very low temperatures that prevail well out beyond Mars. We will need to live off the "ice" out there, even as we need to live off the "land" nearer to home.

Let's get on with this vital research! --- <*PK*>

MMM's Platform for the Outer Solar System

Unmanned Missions

- ***Callisto, Europa, Titan, Iapetus, Triton***
  "Lunar Prospector" type mapping missions (geochemical, gravity, and magnetic maps to provide a knowledge basis for planning future activities, robotic or manned)
- ***Pluto*** Express [budgeted by NASA]
- ***Callisto & Europa***
  Radiation exposure mapping
- ***Titan***
  Synthetic aperture radar mapping of solid, liquid surfacescapes
  Aerostat forward exploration for long-term ongoing study of atmosphere, surface
  Ground stations, rovers, rafts if needed
  Robotic materials-processing testbeds to explore level of feasibility of a partially autonomous outpost
- ***Jupiter***, ***Saturn***, ***Uranus***, ***Neptune***
  Unmanned aerostat atmosphere explorers
- ***TAU*** [(one) Thousand Astronomical Units]
  Stellar Parallaxes Survey Mission

Human Activities Enabling Technologies

- **Nuclear Rocket Propulsion R&D**
  Continuing research on many fronts
- **Artificial Gravity Spaceship Architectures**
  Fixed boom and reel-tether types
- **Cryosynthetic Materials R&D**
  Coping with scarce metals & silicate stuffs

Envelope Pushing Human Outposts

- ***Callisto*** Surface Base (*Port Galileo*)
  Ice Shields, Silicates, Metals, Manufactures
  Orbital Outfitting Depot (*Jove Port*)
- ***Europa*** Surface Base (*Port Rhadamanthys*)
  Teleoperations Centers for *Ganymede* & *Io*
  (Limited Expeditions to *Ganymede* & *Io*)
- ***Iapetus*** Base (*Bonestel Point*)
  Tourism - best land view of Saturn's Rings
  Forward telexploration of Saturnian System
  Paralactic Observatory
  Manufacturing support for *Titan* Effort
- ***Titan***
  Exploration & experimental industry surface outpost (*Port Huyghens*)

COMMENTS? ==> kokhmmm@aol.com

Towards a Frontier of Multiple Dimensions

A Personal Reflection on MMM's November '98 IN FOCUS essay: "On the Essence of the Frontier: the Readiness to Reinvent Everything"

by David A. Dunlop

May I suggest that the off-Earth frontier offers us not just one frontier but at least a frontier of multiple dimensions.

We must achieve a One Planet Economy Before we move to a Two Planet One

The first challenge is the spread of not only us as Earth creatures but of our biosphere's propagation to the near-by environs of the solar systems. I think the L5 vision is something that will be attained almost inevitably as we cross the "economic threshold" of the "two planet economy". I would argue that indeed we have truly not yet attained a "one planet economy". We have made a start but one can start argue persuasively that it is not quite yet one world. The differences in level of economic activity, per capital income and productivity, and integration of economic activities still varies enormously across our planet. That we envision doing so is a result of the satellite communication and the computer age. Sophisticated prognosticators still look at the differences and view rough parity of economic maturity as unlikely until the end of the next century.

It is not clear politically that there is even consensus that there should be parity in the level of economic maturity. The "haves" have not made a convincing demonstration that the economic power they enjoy should be diluted by the rapid growth of the "have nots" of the second an third tier nations. The aspirations of those in the second a third tier however are strong and the market mechanisms of economic growth favor I believe a strong historical momentum toward that situation. As sanguine and optimistic as the vision of global economic maturity might be it is unlikely to occur except as the hand maiden of not only space based communications but space based energy supplies.

The economic threshold toward the two planet economy will be crossed as the capability of creating the space based energy supply is created. Cheap access to space (Leo and Geo) will open the doors to Solar Power Satellite development with a follow-on growth of the Lunar Power System. Advances in controlled fusion technology and the requirement of Helium 3 will provide the compact and high levels of energy to move "quickly" around the solar system. Cheap access to space and cheap and clean energy in abundance could fuel a long boom economy over the next century. Development and higher prosperity will spread around the globe in a way that is environmentally sustainable and in a way that increases the carrying capacity of the Earth.

I believe the first planet to be "terraformed" is the Earth itself. Currently only a fraction of the land mass of our planet is climatically suited for human habitation and human food production. A large energy supply to desalinate and pump water could radically change in Saudi Arabia, the North African littoral, and Australia. We can envision a "designer" planet with increased rain forests created to maintain oxygen supply, a de-industrialized global economic system powered by clean space-based solar-hydrogen-electric systems.

The Economy of the New Millennium

This new millennium economy will be orders of magnitude greater than today's. The economic threshold for the three planet economy will be set in place with the creation and maturation of the Two planet Economy. The push to Mars will occur on the back of the new giant Near Earth Space and Moon economy. A Mars Direct scenario would see its first landing some time in the second decade of the next century. Unlike Kim Stanley Robinson's grim Red, Green, and Blue Mars picture of Mars being developed as conditions and the economy and ecology of the Earth disintegrates and deteriorates, I see a more optimistic scenario.

The vibrant space economy and capability will not only allow a human push to colonize Mars but to use asteroid resources in near Earth space for L-5 style projects and to colonize larger asteroids as a Fourth Stage of a Human Expansion and use of the solar system. These latter applications will again allow an economic system fueled by a now limitless energy supply from space for population expansion and diffusion. You stated "The deep logistical mutual quarantine of the various space frontier sites will offer unparalleled opportunity for social, political, cultural, religious experimentation without attrition to and erosion by a dominant and overwhelming mainstream culture."

Many Dimensions to the Frontier

It is in the context of this development scenario that I see many dimensions to the frontier challenge. It is our psychological nature to presume to extend our current conceptions forward. It is typical of "mother" countries to see their colonies as "children" needing support, guidance, and direction. It is of course an "Earth" family that is expanding. Yet the healthy Earth family produces offspring that struggle to be "independent" as a stage of becoming interdependent as members who will propagate and raise a new generation.

First, Genuinely successful colonies do not remain children politically or economically. Second, we have not defined or discovered a gravitation standard that will permit ease of movement between the Earth, the Moon, and Mars, and Deep Space. Those L-5 colonies around Earth will most likely favor a gravitational standard close to 1 G because of the close proximity and the desire of frequent movement and adjustment between the Earth and these structures. We can't do too much about the Moon's gravity. Adjusting down to and up from the 1/6 G may be a barrier that means many will opt for limited duty tours. The struggle to adapt to 1 G-for those born on the Moon or that elect to stay long term may mean that you can't go back! The same conundrum may well apply to those fully adapted to Mars. We may confront biological frontiers in the process of this expansion that are not so easy to surmount in the long term! Perhaps biology will provide the basis for a "deep logistical mutual quarantine" as much as the time, distance, and energy cost transportation barriers separating the human settlements of the solar system.

A Plurality of Human Species?

It may well be that a two planet, three planet, and fourth stage human economic and population expansion is anywhere from likely to inevitable. Having created this system we may find that natural selection and evolution and our own designer biology will create separate biological branches of homo sapiens:

√ Homo sapiens Terrensis
√ Homo sapiens Selensis
√ Homo sapiens Martensis

A Solar system standard less than 1 G but greater than Mars and Moon gravity wells might create a common ground for these subspecies in deep space L-5 environments. "We" may not remain as one commonly integrated gene pool as a result. Over many generations of adaptations to Mars it may occur that successful interbreeding will not longer occur or be possible. This biological fracture plane may create yet another dimension in the Frontier: that of purpose and ambition. These species may aspire to new and different environments.

Will future Starships carry members of these three humanoid species to find and settle not only a new Earth, but a new Moon and a new Mars? Will our capacity to bio-reengineer ourselves further change the unitary vision of "human destiny" and expansion and fracture it or transform form it even more? Perhaps we will move from being Homo sapiens, a "knowing or wise" species into a self-knowing and self-transforming species. Perhaps a sterile Europa may be "seeded" by a dolphin-like creature designed by homo sapiens for a new ocean world with a new ocean biosphere but capable of intelligent communication with it designers?

It is difficult to specify the politics and economic exchanges within a differentiated set of humanoid and humanoid designed species. The "futures" chess game goes from two dimensional to three dimensional or more. On the time scale of Earth's life development we have seem many forms emerge, transform, expand, and extinguish. The amphibians didn't "go back" to the sea. The invasion of a new land ecological niche transformed animal life. After mammalian forms had developed, new forms went back to the sea. They were no longer amphibians but dolphins, sea lions, whales, and naval submariners.

The expansion of human beings and our biosphere into the new frontier of the solar system is likely to create another "punctuated equilibrium" in the evolution of the life system. This is a frontier whose penetration will transform us beyond the modest shifts that I have suggested. The mass extinctions of the past created room for the rapid redevelopment of new life forms. The pace of change in the next century or two may be much wilder than we can imagine.

Recasting the Directive of Genesis

The dimensions of the new solar system frontier include not only the near term development of the transportation and support technology of homo sapiens, but of biological structure, and psychological structure and identity. In the Garden of Eden, Adam and Eve were instructed to "be fruitful and multiply." In retrospect it seems so simple an ambition for an earthly garden planet. Prospectively we might "be fruitful, divide, expand, and transform." The rock strata show us that this has happened again and again in the past. It seems reasonable that the pattern should apply to the new frontier niches of the solar system. <DAD>

[**David A. Dunlop**. An at large member of the Lunar Reclamation Society since 1989, in 1990 Dave founded **LUNAX: LU**nar **N**ational **A**gricultural e**X**periment Corp., a nonprofit effort to interest high school science and ag-science teachers in experiment guidelines for their students that would yield significant data, e.g. the "Lunar Nightspan Dark Hardiness Experiment." Dave has also served on the Board of Wisconsin Space Business Roundtable, helped with the initial brainstorming of the Moonlink program to have students receive live data from Lunar Prospector, and was the principal organizer of the first annual Wisconsin Rockets for Schools suborbital launch event in Sheboygan, Wisconsin. He then organized a similar participation in Michigan. Dave is especially interested in the prospects for space based solar power, and the development of terracing steps to its realization. Until recently, he lived in Green Bay, Wisconsin, and is currently in Oak Park, Illinois.

Over the years, Dunlop has contributed many thought-provoking essays to this newsletter. David was also a critical early driver behind the recent ISDC '98 Milwaukee Conference at which he organized and chaired the sessions on space-based energy.]

probes to all moons

by David A. Dunlop - <dunlop712@yahoo.com>
Special to Moon Miners' Manifesto

The focus of interest on Europa and the possibility of a European Ocean are going to push the envelope on the design of "small" lightweight probes which are designed to:

A. Get there - Propulsion. Since it takes a lot of fuel/propulsion system mass to get out of of even move around once in the gravity well of a planetary systems it seems inherent that these small probes would be targeted on just one moon with circularization of orbits and lowering of orbits in the manner of Mar Global Observer
B. Maneuver into orbit
C. Perform orbital remote observations
D. Drop penetrators
E. Drop landers
F. Survive "years long" transits to destination and hopefully years long missions of observations.
G. Provide highly reliable transmission of collected data, spacecraft operations data.
H. Survive long term exposure deep space radiation of solar wind and solar storms, survive micrometeor dust impacts, endure high level magnetic fields, endure long term "frigid" environments.

It strikes me that the "market" for probes with these design characteristics is quite large.

Right now the focus is on Europa. However, if memory serves me there are some 66 or 67 planetary moons thus far identified in the solar system. Most of these places are *cold* and Remote. The Moon/Luna, Phobos and Deimos [Mars] are the "tropical" moons, so to speak, of the inner solar system. However the balance are part of the large gas planets systems plus Pluto/Charon.

Thus the exploration strategy for the next several decades can benefit from economies of scale production. Rather than unique design efforts the spacecraft bus design costs could be quite standardized. The NASA Discovery Mission and New Millennium Missions can provide the proof of technology.

The funding for such missions would in most cases still be based on government funding but with a significant drop in the costs of both deep space qualified space craft buses and order of magnitude drops in launch costs the number of government entering the space race should significantly increase. The Discovery Mission costs are approximately $150 M for spacecraft and $50-75 M for launch costs. Delta and LLV are the current staples. The new Millennium series are supposed to provide much lower costs. We will see if they are possible within a $20-30 M range.

Kistler and Venture Star among others, should, if successful, make order of magnitude cost reductions for the launch of small space craft into deep space. This would amount to a $5-7.5 M cost per launch. Of course there is no use to having a reusable spacecraft with short turn around flight capabilities if there is no realistic market for such a craft.

Well folks, a "Missions to the Moons" market could provide a large number of targets for exploration and science missions at a price that "many can afford." Many countries that are now "bit" players could afford "their own" missions. Such missions would be a signature of the countries sophistication in term of strength of university science programs, educational and high technology capability within their borders. "Yes Ladies and Gents you too, for just the price of an obsolete fighter jet can 'own' a moon."

For the first round at least what we know about these many moons would largely be "the scientific province" of the country sponsoring the first probe. It might be a unique strategy to get small countries with disputes to *trade down* their current arms expenditures for weapons purchases for small science missions. They would as part of peaceful stabilization negotiations have to divert money otherwise directed toward armaments to science and education efforts within their own borders, which expenditures can be monitored. This makes it especially painful to cheat since the cheater has a double whammy economically. The military justification of such tradeoffs is that maintaining and building a high tech aerospace skills base is strategic money well spent, looks good internationally, and gives the guys with a handle on the cash a new place to spend it.

Who might such players be? Argentina, Brazil, Chile, Mexico, Saudi Arabia, Iran, India, China, South Africa, Taiwan, Ukraine, Kazakhstan, Australia, New Zealand, Sweden, Poland, Spain. This is just a top of my head listing. It might be more intelligent to simply take the next 15 to 20 countries ranked by GDP after one has subtracted the G-8 and European Union nations.

It seems reasonable to set order or magnitude cost reductions as attainable for such missions over the next decade. The G-8 space budgets under this scenario do not have to increase. The commercial suppliers of the G-8 in essence become the "Radio Shack catalog" for the next tier of space faring nations. If each of the nations mentioned above committed to a moon exploration mission beginning in 2005. over a 5 year period each moon in the solar system would get its own probe by 2010. One launch a month would provide a significant market for new reusable launch vehicles. This proposal defines just one niche market.

I think this strategy is significant because:

First: The basic spacecraft design is such that it invites *commercial vendors* that have flight tested new cost-effective technology in the Discovery and New Millennium Series to benefit from a "if you build it they will come" marketing strategy."

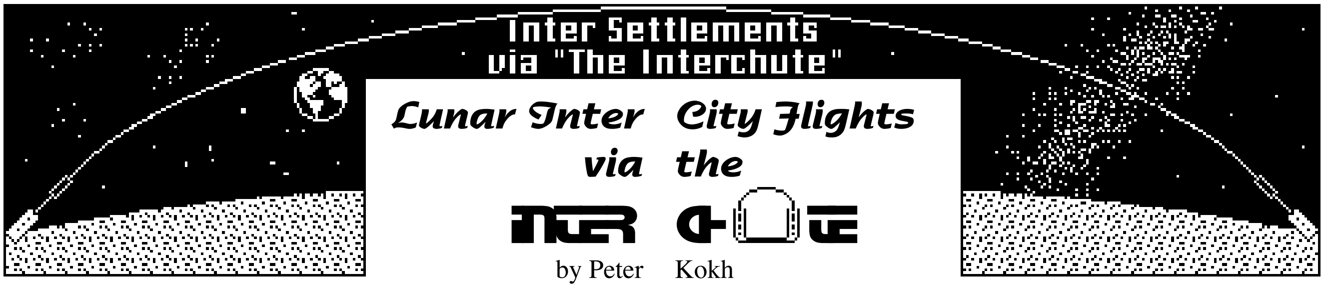
Second: The internationalization of National Space Society, which should really be the International Space Society has suffered from its principal US base, being the focus for a majority of members based in the US. The "First to The Moon and Mars franchises are largely taken. The "owning your own moon" strategy would permit NSS chapters in other countries or such as the Buenos Aires chapter of NSS to rally around the national cause of their own moon. Having a target for your own interest is a spur to maintaining a unique identity. This type of "grass roots" support is a key element in reaching a critical mass of support and publicity in a new country.

Third: A prestige economy budget 'space race' would be encouraged via the UN, and other international scientific groups interested in solar system sciences, aerospace technology. This new space race would also encourage expansion of the Deep Space Network tracking capabilities to handle a much higher volume of missions than at present. Organizations like AMSAT and the American Radio Relay league already are international in the scope of their communications and collaborations. These deep space Missions to the Moons might become an evolutionary jump for existing groups with the technical expertise to wrestle with the support and logistics issues of deep space tracking and communications. They are the beginnings of a constituency in many of the countries that might sponsor these missions.

Of course this strategy reflects the parochialism of basing the strategy on English speaking countries. Since I speak Spanish I would also suggest jumping the language barrier and target Brazil, Argentina, Mexico, Chile, and Spain. The recently organized MercoSur organization has drawn the South American countries into closer trade relationships. Both Spain and Brazil have nascent space industries. Small university satellite projects have been undertaken in Mexico and Argentina. The beginning seeds are there for a second network. We have a significant bilingual community in the US to support ties to a Spanish speaking group of partner organizations.

This strategy outline is suggested as a means of leveraging the current interests and technology trends into a vigorous moon exploration program. For the US, European Space Agency and Japan, the International Space Station, Mission to Planet Earth, and Commercial Communications Satellites will remain the dominant agenda. The few, the curious, and the underfunded, however, might fill a niche which steps up interest in the solar system, space, and educational participation. The diversity of moon environments means a rich harvest in planetary science and a large number of opportunities for national and corporate "firsts in space". <DAD>

* [It would seem logical to break up any such cooperative effort into Jovian, Saturnian, Uranian, and Neptunian exploration associations. - Editor.]



Lunar Inter City Flights via the INTER CHUTE

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 concept 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 = V2 / (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.

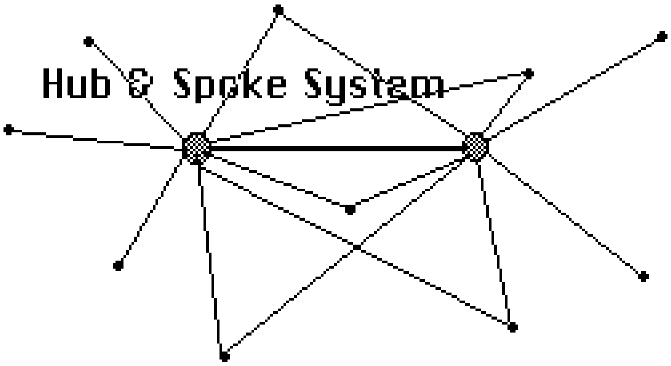
This transport system demands an extremely high level of precision accuracy, within a centimeter perhaps, after a volley of hundreds, even thousands of kilometers. Anything short (long, off to the right or left) would mean certain vaporizing death on impact at c. 1.5 km/sec. Such precision could never 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? But here are some suggestions 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

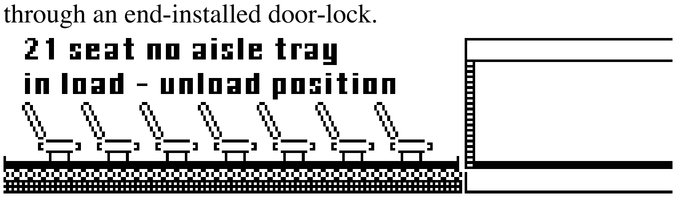
Interchute coaches are not rockets. They are passive bullets or projectiles. The acceleration and deceleration both take place entirely within the "barrels" of a pair of electromagnetic "cannons" *"aimed down each other's throats"*. Properly set up, there would be no need for "mid course corrections". 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

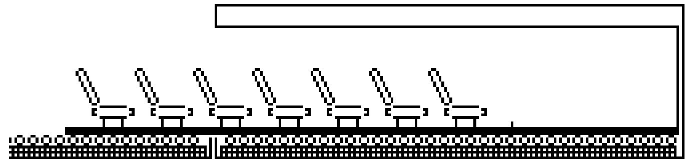
Interchute travel on the Moon would be very swift, with a maximum of one hour flight times, but in most cases much shorter. As such, accommodations can be rather spartan: no berths, no snacks, maybe even no toilets. All such facilities would be found in the terminal buildings.

LOADING & UNLOADING PASSENGERS

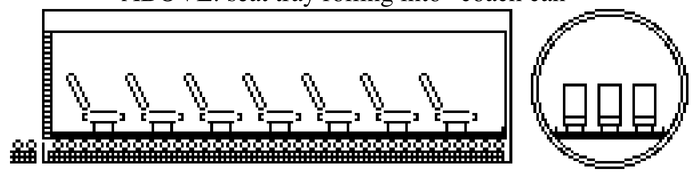
Economics (demand for lowest ticket prices) will demand "maximum packing" of the coach cans. An "aisle-free" arrangement can be effected by using pre-boarded seating trays that can slide into (and back out of) the Coach Can through an end-installed door-lock.



ABOVE: seats entered from side platforms

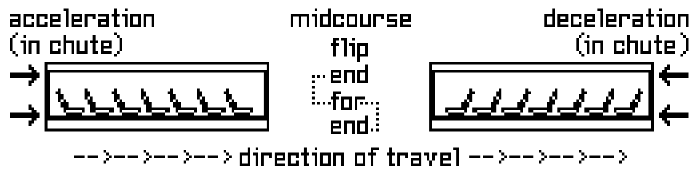


ABOVE: seat tray rolling into "coach can"



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 glideslopes. 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 containerized 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 they generated. High speed rail (see MM Review #13, AUG 13, pp. 9-15 "Lunar Railroads") or Maglev would be the choice. [http://www.lunar-reclamation.org/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>

Our Future on the Moon: Some FAQ's

MMM Editor Peter Kokh replies to
Kathiann M. Kowalski <kowalski@en.com>

Briefly, by way of background, what is your background outside the Artemis Society? (e.g., job and subject field)

[A] I am a member of Artemis since Spring of '95. I have been editing and writing Moon Miners' Manifesto for the past twelve years and my principal involvement is with the Lunar Reclamation Soc., an independently incorporated organization which serves as the Milwaukee chapter of the National Space Society.

I have no professional background in space related areas. Space has been my hobby and passion since I was old enough to read (age 4+, 5 1/2 decades ago, before the leftover Nazi V-2s were brought to the U.S., before we bounced radar off the Moon) so I am entirely self-taught in this area. Prior to launching MMM, I had done considerable deep and wide-ranging research, brainstorming a novel about lunar settlement ["The Cinderella Project"] - the novel never got written but much of that research has found its way into the pages of MMM. My approach has always been that of a "generalist", rather than a "specialist".

I have a BA from Marquette U. in Philosophy and was thrown out for departmental party line noncompliance on the eve of receiving my Masters. I worked in industry (blue collar) by choice for many years, but the past decade have had my own "custom" home repair/remodeling service - thus my interest in how we could make ourselves "at home" on the Moon. I am now on disability after a very bad fall in 1997.

Explain to a junior high student why you think lunar enterprise may be feasible or advisable?

[A] The Moon has several assets.

(1) Low gravity. That means that anything you want to build in space, in Earth orbit for example, that will need a lot of building materials, can probably be built more cheaply from stuff rocketed off the Moon than from stuff lifted up from Earth - even though Earth is much closer. Time and distance are less important than fuel and energy. Of course, first you have to have the factories on place on the Moon. The Moon is rich in materials out of which to make metal alloys, ceramics, concrete, glass, fiberglass, and glass-glass composites (stronger than steel). So building materials - for *space* construction projects - are a big incentive. Remember, it makes no sense to bring those materials down to Earth itself. We can supply them much more cheaply here.

(2) There are 3 Moon-based schemes to solve Earth's long range energy problems in ways that will not kill our planet with pollution. One is to build large solar collectors on the Moon, one array on each limb (edge as seen from Earth) so that one or the other will always be in the sunlight - and beam the energy by microwave or laser via satellite relays to power grids on Earth. Another is to use building materials from the Moon to build giant solar power satellites right in space to do the same thing. The third is to ship lunar helium-3 (the Moon has enough to supply all Earth's energy needs for a thousand years

while Earth has none, except from decay of manmade nuclear materials - enough only to experiment upon). If we were ever to conquer the great engineering problems in the way of nuclear fusion, helium-3 would be a much more ideal fuel than deuterium or anything else as it emits only charged particles that can be turned into electricity directly, and no neutrons or any radioactive particles - it is ultra clean! One shuttle external tank filled with liquid helium-3 could provide all the energy this country uses in one year, had we the plants in which to burn it. Helium-3 exists only in the upper two meters of the pulverized lunar Moondust blanket or regolith, and comes from the solar wind.

How soon do you think commercial enterprise on the Moon could actually be feasible?

[A] Up front costs are high. Transportation costs will eventually come down. Then there is the cost of putting up the initial capital equipment and the manned operation to keep it running. No one product (except Helium-3) promises to make the Moon a thriving place. But the diversity of possibilities *does* promise this. What we need is companies or consortia with enough vision and willing to wait a decade or so before profits start rolling back. If we had the vision, we could get the ball rolling now. Predicting attitude changes is much more risky than predicting technology improvements or breakthroughs. I do not look for the government to get involved and unlike most space supporters, dearly pray that it never does, as, 70 years after Little America, where are we in Antarctica? If we want industry and settlement on the Moon, it is important to keep government out, and to encourage government to undertake those things that do not promise economic justification, at least for a long, long time - like undertaking manned exploration of Mars.

What do you see as the biggest obstacles to overcome? How much relates to technology? How much relates to other factors?

[A] Cheap Access to Orbit is one half of the energy problem. The other half is Cheap Access from Earth Orbit to the Moon, which is being ignored. Other technology problems that are being ignored by NASA and space supporters alike, are the development and debugging of potential startup lunar industries - metal alloys, glass composites, etc.

There is also more exploration needed. ***Lunar Prospecto***r for which NASA takes credit, was begun and designed down to the last nut and bolt outside NASA. We need ground probes at the poles to check ice thickness, composition (it should include carbon oxide ices as well), hardness and the engineering feasibility of mining it. We know that there are lavatubes on the Moon (it is not just an educated guess) but we need to map them as they will provide ready made shelter for such volume-hungry operations as industry and warehousing. But only the Oregon L5 Society, with some help from the Lunar Reclamation Society, is pursuing this project.

Given the transportation, exploration, and technology predevelopment homework - all of which can be done within the decade if truly realistic amounts of money are found - then all that is needed is the hardest thing of all - attitude. Business and industry have been taken over by young punk MBAs who think the only thing that is important is to show a profit the next quarter. No risk, no gain, no Moon.

In what "order" do you see lunar enterprise developing? Which ventures will likely occur first? What next? Why?

[A] Everyone talks about lunar oxygen, but to paraphrase a famous New Testament quote, “man cannot live by oxygen alone”. It makes sense to plan oxygen production so that there are other byproducts like iron, titanium, etc. Iron is by far the easiest, as pure unoxidized iron powder can be extracted from the regolith simply by passing over it (e.g. on a conveyor belt) with a magnet. But iron is not yet steel. Making serviceable alloys is a more complex problem as it means also extracting the alloying ingredients.

Sintered powdered metal technology is one way to put iron particles to work right away making many useful products where high performance is not needed. Aluminum, true steel, titanium, and magnesium of the quality we’re used to are products that’ll come down the line - not right away. Without organic paints, steel has a severe corrosion handicap, unless we alloy it with chromium to make it stainless. So chromium extraction has to be a priority.

Glass-glass composites are a prime early candidate for a versatile building material. We can make fiberglass with a high melting point from lunar soil. Making a lower melting point glass to use as a composite matrix awaits a simple attitude change. It is absurd to plan on bringing lead from Earth for this purpose, as Space Studies Institute would do, when simply “doping” the mix with lunar sodium and potassium would do the trick. It has always been hard to teach old dogs new tricks.

We can also make cement, use lunar pebbles for aggregate, and reinforce it with lunar fiberglass.

Now what do we make with all these building materials? First and foremost is lower performance, simpler, and heavier components for additional factories, as this will lower the cost of importing stuff from Earth. Next is modules for pressurized shelter - so we can cut the amount of imports needed for base expansion.

But before any of this, we have to figure out how we are going to power our operations through the 14.75 day lunar nightspan. No one has ever been on the Moon at night. Temperatures are not the problem, energy is. The easy solution, nukes, is one that politics on Earth may not allow. It makes sense to plan a backup (even if we do get to bring nukes). There are a lot of possibilities: fuel cells could combine freshly mined oxygen with hydrogen to produce electricity and drinking water. Hydrogen could be brought from Earth (I’d suggest as Methane since we also need carbon: methane is much easier to ship), or extracted from the soil as a byproduct of helium-3 mining, or electrolyzed from lunar polar ice, along with carbon from carbon dioxide ices and piped, as methane, to sites where it will be burned).

Another option is dayspan solar heat concentrators to melt pools of soil and use the heat for steam generators throughout nightspan. We need to debug all options and reengineer them for the Moon.

Your online material [www.asi.org/mmm] discusses potential for mining gasses. How would you explain to a young person why He-3 would be an ideal fuel for fusion? [See my answer to question 2 above] Apparently the fusion reactors still need to be engineered; what needs to be done?

[A] We need to learn how to contain the fusion plasma with less energy than we get out of it in the process. Thirty years ago, it seemed it would take 30 years. It still looks that way. But we have made real progress and are a thousand times closer to "breakeven" than we were back then. Once we have fusion, we still need to make major improvements, as the ignition point for helium-3 is considerably higher than for deuterium, so it will require a "2nd generation" plant. But the promises of helium-3 are so great that once fusion is demonstrated for deuterium, the race for the 2nd generation plant will be on. Some experts think we will never be able to do it. But then most experts once thought aviation was impossible too, and breaking the sound barrier, etc. We all have limits to our vision and I confess I would say "never, ever" to FTL faster than light travel.

Why is 600 degrees F a "magic number" for driving off Solar Wind gasses?

[A] It is just the amount of heat needed to release the gases from their physical [not chemical] adhesion ("adsorption") to the fine soil powder particles.

How do we know all these gasses have stayed around in the regolith, waiting to be harvested?

[A] Easy, from testing representative returned Apollo moon-dust samples. Plus, in ordinary conditions, it never gets anywhere near 600 degrees on the Moon.

What would it take to make gas mining economically practical?

[A] We should engineer *all* "earth-moving" equipment to be used on the Moon for road building, site preparation, mining, or whatever, so that it heats all soil moved in the process and collects the gasses and store them as a valuable industrial resource. This "primage" should then be the first lunar industry, because it will set us up for much greater lunar industrial diversification in the long run.

Byproducts will be hydrogen, normal helium-4 useful for cooling superconductors and other uses, carbon, nitrogen, and the noble gasses neon, krypton, and argon (along with helium) for producing fluorescent and neon lighting. Some types of lunar soil have been more efficient absorbers of the solar wind than others. Dark volcanic soil rich in ilmenite, an iron-titanium-oxide, are especially rich in gas.

What other materials do you think could be effectively mined on the Moon?

[A] Most abundant are silicon (electronic components and glass), oxygen, the 4 "engineering metals" (iron, aluminum, titanium, magnesium), and calcium (for cement). Next in abundance are elements useful both in making alloys and in producing coloring agents (a psychological, if not a technical necessity), and also sulfur and potassium.

Among the very rare elements on the Moon are such things we find absolutely necessary on Earth such as copper, zinc, lead, gold, silver, and platinum. To supply these we could try using bacterial cultures to concentrate them in a bioextraction process. Some think that nanotechnology will be the route to take for such extraction processes.

We could also brainstorm orbital chemical mappers refined enough to see if any of the zillions of lunar impact craters are like the one in Sudbury, Ontario, rich in asteroid-donated copper, nickel, and iron. Or we will have to mine handy asteroids for these metals. I much prefer that to getting them from Earth, as it must be our long range goal to expand the human economy to the entire solar system.

Would manufacturing be feasible on the Moon? What types?

[A] We need to manufacture housing components, then vehicle components, tankage, furniture, furnishings - anything that can be built or made from materials we succeed in processing from the soil. The less we have to import from Earth, the more feasible economic self-support will be. Never forget that *until* the base is self-supporting, it will not be "permanent". Politicians can pull the rug out *at any time*.

Bear in mind that anything Lunans learn to provide for themselves, they will be able to market at a profit, anywhere else in space, because of lower fuel costs thanks to lower lunar gravity. If we build giant resort complexes in orbit, much of the building components and furnishings will come from lunar factories. If not, these complexes will be much more expensive, driving up tourist ticket prices. In like fashion, many of the components needed to open up Mars can be initially sourced from lunar factories more cheaply than from Earth.

What about things that include elements we can't get from the Moon or that require too complex a manufacturing process? Here we need an "Institute of Lunar Industrial Design" that will redesign everything into two subassembly packages, one lighter weight, more complex, and/or manufactured from elements we cannot yet economically produce on the Moon. This subassembly would be made on Earth and shipped to the Moon and there mated with a chassis-like subassembly of heavier, less sophisticated components, made acceptably from lunar materials. This dual sourcing will make these items much less expensive than if the whole item was made on Earth.

Another lunar export I have seen mentioned only once, is food - agricultural products. Yes, it will be harder to grow stuff on the Moon. But at least half of all protein and carbohydrate is oxygen, which we know we can get from the Moon, and the other half is hydrogen and carbon which we may be able to get from the Moon. And the water of hydration is 89% oxygen. Once food production costs are low enough, lunar agricultural products - even water!!!-- could be shipped more cheaply to low Earth orbit resort complexes than up from Earth. The *only* things it pays to ship from Earth are these three: people, tools, and seeds. someday, the Moon will supply these too.

Regarding tourism, what "attractions" do you think would generate enough interest and be affordable by enough people to make a venture economically attractive?

[A] Much sooner than anyone thinks, we will have lunar "flyby" = "loop the Moon" = "Cowjump" tours. We are on the verge of the first tourist suborbital hops. Once we start putting people in orbit for a week, the only extra cost to send them on a swing past the Moon and back is another tankload of fuel.

As far as ground excursions go, those who go to work on "working vacations" (as some now pay to go on archeological digs) will get to go much sooner, and for much less money, than traditional tourists. Taking on some temporary on site job will be the cheapest ticket. "Join the Navy and see the World" (or lot's of water and dockside dives, at least!)

As for the sights. number one must be Earth itself, hanging over the lunar horizon. Number two (for those who make it to the farside of the Moon) will be the unimagined glory of the Milky Way in the nightspan sky with no Sun, Moon, or Earth, in the sky to blind the viewer. For amateur astronomers, just looking at the unblinking stars, and being able to see ten or a hundred for every one they saw on Earth.

Next come views from crater rims (there will always be those dull "dah!!" types for whom when they've seen one crater, they will have seen them all.) Views of lunar rilles. Exploring expeditions in lunar lavatubes, again for the more adventurous.

Experiencing lunar gravity in general, while sleeping, having sex, dancing, playing ball, etc. will provide cherished memories for many. Arthur C. Clarke suggested that lunar flowers might grow magic-forest tall in the low gravity, so that lunar flower gardens might be favorite places to visit, for wedding pictures etc.

Finally, for those who will let themselves entertain such ideas, getting the feel of what it would be like to pioneer a raw frontier community from scratch, getting in on the ground floor, making traditions rather than kowtowing to them, etc. will provide a life experience you could not buy on Earth for any amount of money, even if they choose not to stay on.

Any other thoughts you'd want to share with a young person about future development of the Moon?

[A] Take a look at all your favorite things. Some of them will include activities you may not be able to do on the Moon, or for which you might not be able to find satisfying substitutes - at least not right away.

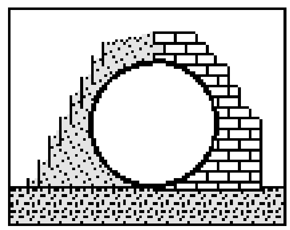
The early days of the frontier will be very rugged, and are only for those for whom the psychological benefits of pioneering, being able to start over, etc. outweigh the material sacrifices that they will have to make to do so. Unlike the picture painted by media science fiction, space will *not* be the place to go for "the latest in creature comforts". A hundred years ago, those who wanted the best life had to offer in a material sense, stayed behind in "Baltimore" and other genteel sophisticated cultured Eastern cities. Those for whom freedom, starting over, doing things that made their lives really meaningful however full of hardship, those for whom these things were more important - they were the ones who pulled up stakes, took the no-promises gamble, went west and put down new roots, getting their finger nails dirty with building a new and fresh life, reinventing culture and civilization for themselves and others.

The frontier is for those who feel out of place in the *old* world into which they were born. Even in nature, new niches are explored, tested and colonized by those shoved out of preferred places. In one of nature's great paradoxes, the frontier is for the "second best", those not good enough to fit in well in the given setting, but who do have what it takes to help start all over where there are no sacred cows.

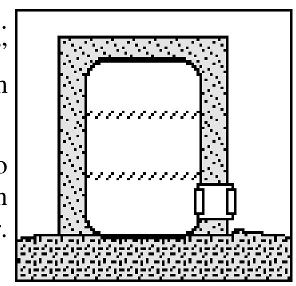
Consider all this and be honest with yourself. You may decide the frontier is for you. But you may also decide that your best course is to support the frontier from a distance, staying home where you are in the groove. The younger you are, the more resilient and supple and flexible you are. Now is the time to change any dead-end mindsets. To the Stars through our own hard work. Ad Astra per Ardua Nostra. - **PK**

MMM #122 - FEB 1999

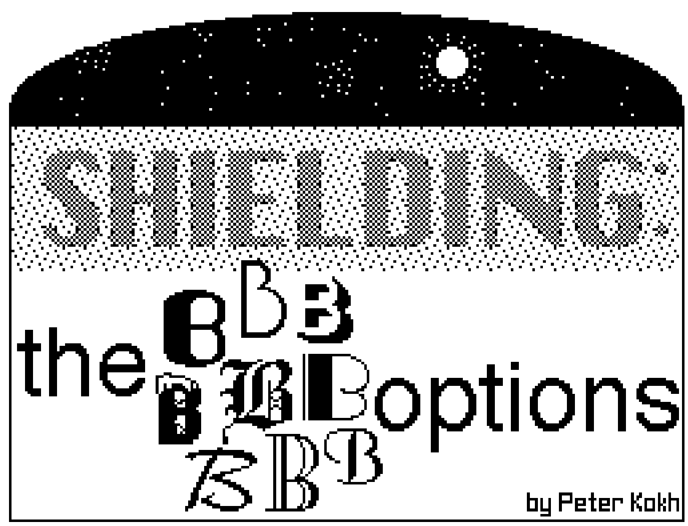
Shielding Accesoriesto Jump-start Lunar Industry



The first lunar outposts, and the first facilities at any subsequent site, even at a lavatube site, will surely be surface ones, requiring shielding from cosmic radiation, micrometeorites, thermal extremes, and solar flares. The first lunar construction "trade" will be shielding emplacement, with accompanying design architectures.



In this issue, we delve into some of the options early "moon roofing" contractors may consider. See just below.



Everywhere in the universe, not blanketed by a thick atmosphere of some kind, must be shielded from cosmic radiation incoming from all directions, from every point in the sky. Depending on where we settle, we may also need shielding to protect from solar flares, micrometeorite "rain", and extremes of hot and cold temperatures. Shielding is "Job One" on the Moon, in free space, among the asteroids, on space ships on long journeys - and, yes, even for Mars.

Decisions on how we are going to shield the first Moonbase, its expansion units, and subsequent installations on the Moon (or on Mars) have received a lot of attention - but not enough. This is a nonpostponable task. Some options are nearer term in the sense of requiring less capital equipment and/or less manhours exposed out on the surface. Others are longer term, in the sense of being enabled by early lunar (or Martian) industries.

We have looked at the question more than once, and the reader is referred to these past articles, by Peter Kokh, unless otherwise indicated:

MMM # 1 DEC '86, p 2, "M is for Mole"
MMM # 5 MAY '87 "Weather"
republished in MMM C #1
MMM # 25 MAY '89, p 4, "Lava Tubes"
republished in MMM C #3
MMM # 37 JUL '90, p 3, "Ramadas"
republished in MMM C #4
MMM # 55 MAY '92, p 7, "Moon Roofs"
republished in MMM C #6
MMM # 74 APR '94, p 4 "Shielding & Shelter"
republished in MMM C #8
MMM # 89 OCT '95, pp 3-4. "Shelter on the Moon: 'Digging-in' for Longer, Safer Stays", P. Kokh
republished in MMM C #9
MMM # 94 APR '96, p 14. "Shielding Artemis Moonbase", Greg Bennett
republished in MMM C #10

INTRODUCTION - THE "A" OPTION

This is simple: we 'plop' a ready made habitat on some level ground, and then scoop or drag up regolith and pile it up against the sides and over the top. There have been many suggestions how to accomplish this:

- some rely upon onsite manpower,
- some rely on remote manpower, teleoperation from Earth
- some would involve automatic or robotic equipment.

In all cases, the idea is to minimize the mass of equipment needed, not necessarily to get the job done faster.

"Option A" has some serious shortcomings.

- Piled shielding is crude in shape, defying attempts at design and style. More to the point,
- it makes add-on expansion difficult, as some of the amorphous hard-to-handle shielding mass has to be "removed", and the existing structures "dusted off" to enable pressurized connections to the new expansion units.

A BEVY OF 'B' OPTIONS

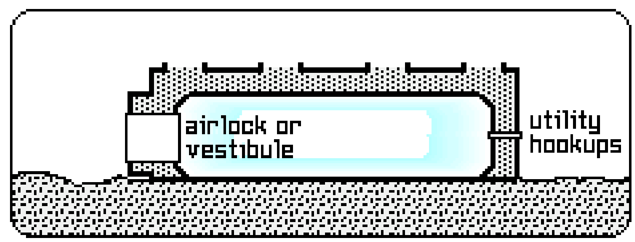
One way I've frequently used to brainstorm multiple approaches to a topic or theme is to browse through the dictionary, often just one letter section, and see how many words evoke a fresh insight. In this case, I could have used any letter, but since "bags & bricks" have been the hot item on one of the Artemis mail lists brainstorming Moonbase options, I chose the "B" section of a dictionary. Here are the results, upon which I have tried to impose some sort of order.

Beneficiation ("Primaged" Regolith)

The first improvement I'd strongly suggest to the point of insisting upon, is that any regolith to be moved in grading the site and/or subsequent covering of habitat hulls be first "primaged" or mined for its volatile gas content (hydrogen, helium, neon, argon, nitrogen, carbon) with which it has been enriched through eons of buffeting by the solar wind. This can be done by simple heating. In the same handling, the regolith can be mined for free (unoxidized) iron fines by passing it under a magnet. While this will only minimally "improve" shielding quality (removal of iron fines will reduce any secondary radiation), the real purpose is to put in place a "habit" that will provide feedstocks for a whole suite of useful lunar industries. See MMM #38 SEP '90, p 4, "Introductory Concepts of Regolith Primage", by Peter Kokh. [republished in MMM C #9]

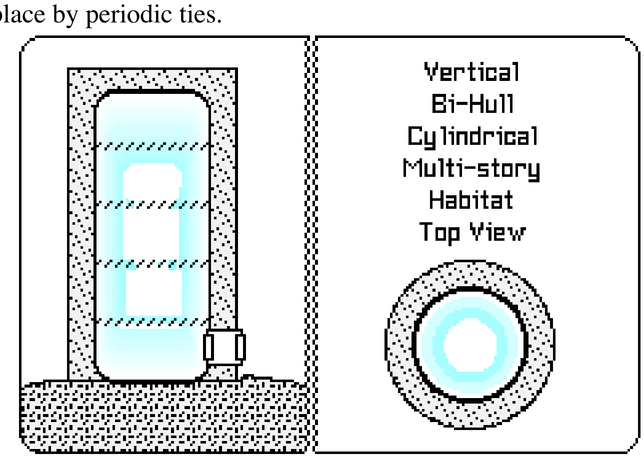
This said, here are some simple "B" Options that do not otherwise require on site industry. As such they might be considered for initial beachhead emplacement.

Bi-Hull designs incorporate a fillable hollow space in the package assembled on Earth. Neat and convenient, allowing "clean & easy" external hookups, but could take up precious cargo bay / hold space unless a special faring was used. The weight penalty would be real but not necessarily major. Lunar regolith would be poured through topside openings on site.

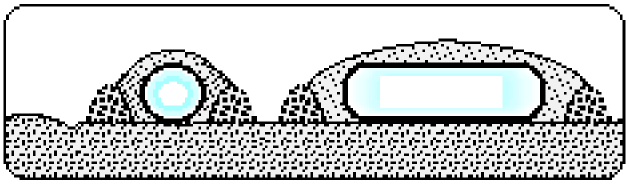


Bags (saddle-) use the same ready to fill concept, but address the weight and cargo bay space penalties by using a durable fabric that hugs the hull during shipping instead of a fixed metal outer shell.

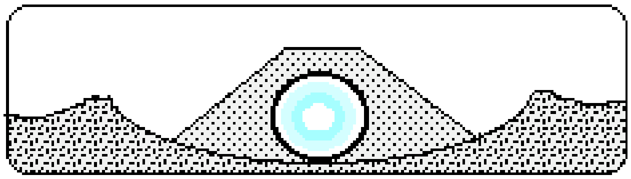
Such a "bi-hull" concept would work particularly well with multistory vertical cylinder habitats that would otherwise be very hard to shield. A fabric outer hull could be kept in place by periodic ties.



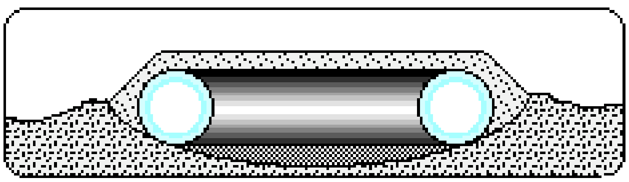
Boulder Banks - In many farmland areas, you may have seen rows of piled up stones and boulders that serve as fences. These were removed from adjacent fields during initial plowing. In similar fashion, boulders and rocks removed from a site in grading, could be used to make "retaining walls" for shielding.



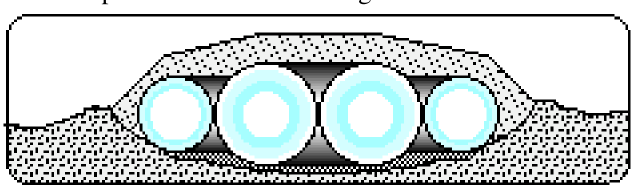
Bowls (craters) Using the rims of small craters to impound the regolith shielding might seem to be a good idea. But the ratio of rim-over-floor height to width offers little advantage over flat sites.



However, a sized-right crater bowl might be ideal for deployment of an inflatable torus habitat.



Or, better yet, a multi ring torus outpost, so designed as to use up most of the "donut hole". The idea is to design the habitat complex to take full advantage of the site.



BETA-SHIELDING - We can make major improvements to shielding structures by using regolith in conjunction with various products made from materials that have been extracted from it, e.g. iron, ceramic, glass.

Principal significant design advantages to be gained are:

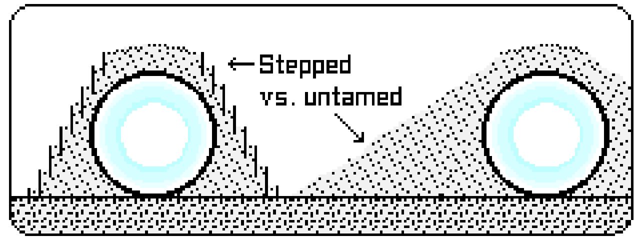
- reducing the footprint of the shielded structure so that neighboring structures can be clustered more closely
- making expansion hookups (connection to new units) easier

These goals can be better achieved to one degree or another in several ways:

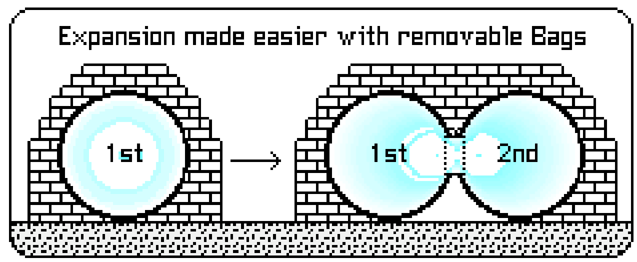
- vertical retaining walls that incorporate hookup service runs
- containerized removable shielding along vectors of projected expansion
- creating bays of "lee" vacuum, protected from cosmic rays, solar flares, and the micrometeorite rain, through construction of hanger space under which unspecified habitat and lab modules can later be placed and hooked up to one another without the nuisance of "contact" shielding.

Some of the accessory items required might be remotely telemanufactured on site (along with piles of pre-primaged regolith) prior to arrival of the outpost erection crews. The equipment required for such manufacturing would kickoff lunar industry.

Baffled, Benched Berms - Regolith can be bermed in steeper slopes if retainer "risers" made of iron, glass, or ceramic are added to 'staircase' the berm. These embedded "risers" act as caissons. This will reduce the site footprint and allow closer positioning of additional modules added at a later date.



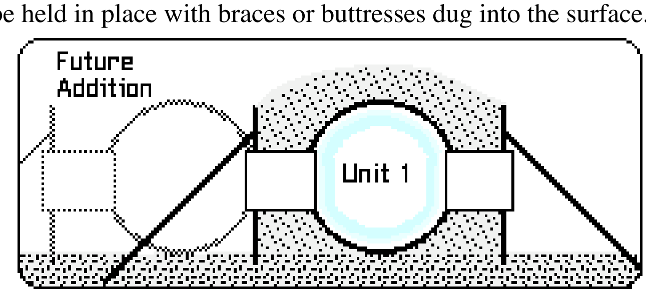
Bags - Lightweight but durable sack-bags brought from Earth, or made on the site of felted glass fibers, can be filled with regolith and piled sandbag fashion around the habitat module(s). The advantages would be twofold: steeper slopes and easy disassembly to allow clean connections to expansion modules.



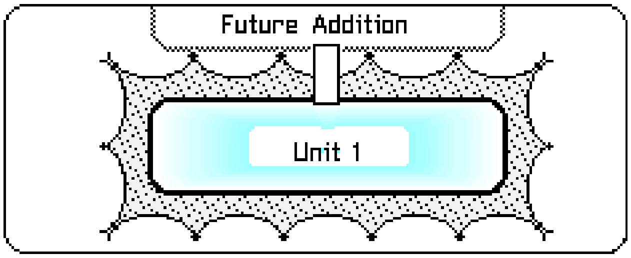
Batts - Elongated bags, reduce the number of shielding units to be handled. Or could we manufacture local fiberglass batts in such a way that impregnated them with densifying regolith powder, making them easier to handle and rehandle?

Bricks & Blocks These would stack the same way as sack-bags, but would have two advantages: no bags to break and therefore less fragile, and no bags to bring from Earth or make of less than durable materials on site. Brick-blocks could be turned out by vibration-tamping regolith in a slip mold while sintering the surfaces with solar heat or microwaves. All that would be required is a few molds and an automated assembly line process that would end in a stacked stockpile, ready to restack around the base modules when the crew arrives. The challenge of both bags and brick-blocks is to find ways to keep out-vac man-hours (crew exposure time) to a minimum.

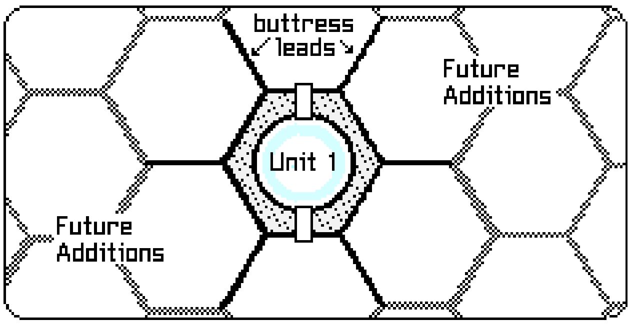
Braces & Buttresses - A retaining wall of sheet iron could be held in place with braces or buttresses dug into the surface.



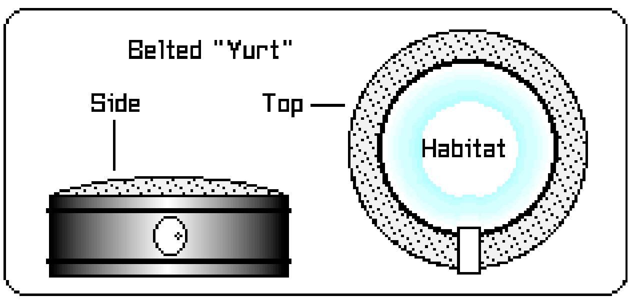
Bayed caissons - An unanchored caisson wall could be held in place by using bayed sections, concave to the outside. This is best illustrated in a plan (top view). The individual concave/convex panels could be made of crude cast iron.



Beehive caisson - A Caisson could be built in a hexagon pattern with the leads serving as buttresses. This would favor circular designs for the habitat module or complex within, e.g. a vertical cylinder or perhaps a torus - a rather restrictive architectural choice.

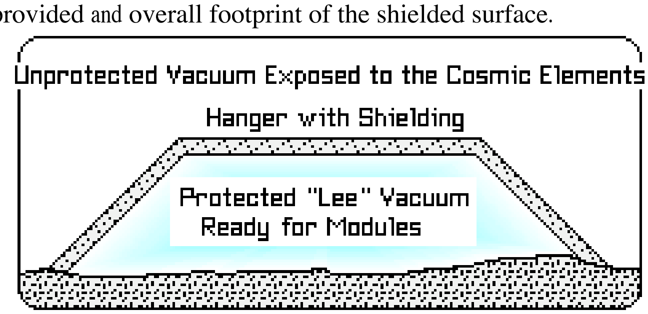


Belted caisson - A cable-belted circular caisson may like a Mongolian "Yurt" or perhaps a Navaho "Hogan".



Barrels, Bins & Bottles - Open-topped bins filled with regolith could be stacked and unstacked in like manner. Bins could be made on site of ceramic or of sintered iron fines. They would only have to stand up to being handles 2-3 times. Bins of crude fused glass (or cubic bottles, if you will) are another possibility. Empty barrels from Earth that had no better reuse (that does seem rather unlikely) would serve as well.

Bunkers - Various structures (Hangers, wide bridges over rille sections, etc.) designed to provide non-contact shielding in the form of "lee" space, spacious bays of vacuum protected from the cosmic elements. In such protected preshielded space, a wide variety of habitat complexes can be built with considerable convenience and freedom within the height clearance provided and overall footprint of the shielded surface.



We covered such options and designs at length in MMM # 89 OCT '95, pp 3-4. "Shelter on the Moon: 'Digging-in' for Longer, Safer Stays", by Peter Kokh. [republished in MMM C #9]

Beam & Post - A structural system by which bunkers or hangers might be built of iron or glass composite. Later on, aluminum, steel, titanium or magnesium could see service. Sheet metal or panels of fiberglass reinforced glass panes could be affixed to this skeletal structure and regolith shielding deposited on top, creating an artificial space analogous to that provided by lavatubes, but smaller in scale.

CONCLUSION - These "B Options" likely just touch the realm of possibilities. It is clear, however, that if we are look beyond a one-shot lunar outpost installation with no provision for growth, that architectural accessories for more convenient and flexible placement of regolith shielding will be one consideration in choosing early lunar startup industries. **<MMM>**

Hexapotency Toning Centers

Lunans Beefing Up for Earth Visits

by Peter Kokh

Gravity on Jupiter (had it a surface!) is some 2.65 times as great as Earth's. We shudder or cringe, just thinking of the idea of weighing nearly three times as much as we do now. What a burden it would be to lug all that around! That would be the lot of any sorry volunteer stationed on an aerostat observatory station high in the Jovian atmosphere.

Now put yourself in the shoes of the future native born Lunan, or even in those of a settler who has been living in "sixthweight" (1/6 th G) for some years. They will really cower at the idea of weighing not merely something less than three times "normal" but a full six times as much as that to which they are accustomed. True, they just have to get used to 5/6ths of a G more, not 1.65 G's more, but it isn't the amount of the G difference, but the ratio that daunts. The ratio sets the slope of the hill that must be climbed to "get in shape" for the prospective visit (whether to Jupiter *or* to Earth).

How will native born or *naturalize*d settled-in Lunans beef-up their muscle tone and strengthen their cardiovascular capacities in order to "manage" a visit back to Old Earth without finding themselves spending most of it in bed or a lounge chair? What's the sense of spending all that money to go back "home", perhaps to see and experience for the first time the open skies, endlessly flowing fields and forests, the mountains, and such sports as flying and soaring and sky-jumping, sailing and canoeing, and skiing and spelunking, and on and on? What's the sense - if you are not going to be "up to it" when you get there?

The easy way out is to settle for ersatz experiences in the local Virtual Reality Suites. But our question remains. How could one tone up muscles and heart alike so that a real visit, for many a Lunan the experience of a lifetime, could be properly enjoyed?

LUNAN FITNESS - THE STARTING POINT

Isometrics, impact and momentum breaking, mass acceleration exercises - in part, some muscle loads will be the same anywhere in the universe because they depend on inertial forces. Contrary to popular wisdom, "weight" is not an inertial force, but the resistance (virtual acceleration) to that force and would-be freefall offered by the barrier surface of a planetary or planetoid body.

Horizontal versus vertical exercise and acceleration or deceleration. Sports active persons will get some amount of helpful Earth-normal horizontal exercise, especially in "contact sports". Sedentary persons will get almost none. They will start their toning up from a much lower plateau.

But even the well-exercised Lunan, however fit for all the sundry challenges living on the Moon can offer, will fall far short physiologically when it comes to taking on a trip "home", especially a trip in which some of the many activities Earth offers are to be enjoyed. The muscles and heart will be overtaxed. The result will be incapacitating fatigue at best, and dangerous, potentially fatal overexertion at worst.

SHORT CUT ALTERNATIVES THAT FALL SHORT

Exoskeletons , and similar arm and leg power assist systems (the "prosthosuits" in B. Alexander Howerton's "Project Avalon") have been proposed by some science fiction writers to handle the challenge of returning to Earth by people who have become conditioned to the Moon, or even born there. Custom tailored exoskeletal suits would be expensive. The availability of individually adjustable suits in a few standard sizes could reduce costs.

These devices *would* serve as handicaps for under-developed Lunan musculatures, but they *would not* help Moon-comfy hearts and cardiovascular systems meet the comparatively severe earthweight stress even of minimum work resting mode. What good would exoskeletal muscle assists do if one were left in a constant state of near fainting from cranial hypotension (low blood pressure to the brain)?

In Ben Bova's classic "Millennium" [Random House, 1976], Kinsman, the hero, is fitted with a surgically implanted heart valve assist to help him survive a trip to Earth to defend lunar independence before the U.N. - and still dies from the exertion!. Not many Lunan pioneers would be willing to go to such lengths for a visit or vacation, even if they could be made risk free.

Except for sudden emergency trips, where there isn't time for proper conditioning, there may be no substitute for the slow gradual workup and maintenance of "Earthtone" and conditioning. Of course, many will try steroids and other drugs to hasten the quest for "hexapotency", the ability to manage activity in a gravity field six times "normal".

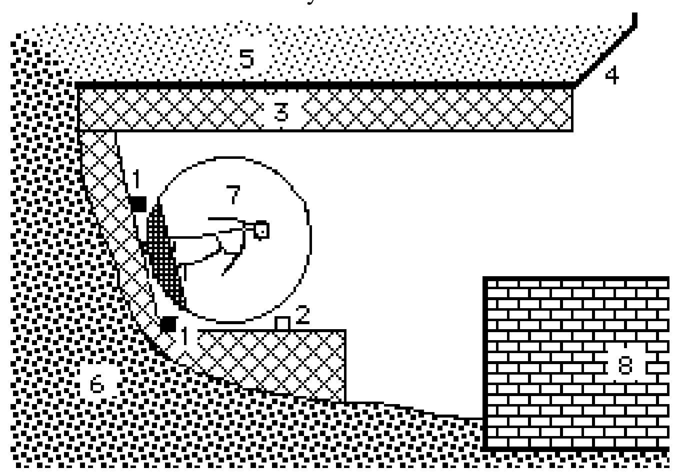
THE GRAVITRAK

In two previous articles, we described a device by which a "higher" gravity load could be simulated. The "Gravitrak" or "Nadirrail" would involve facilities aboard MagLev cars (even a train of them) circling an appropriately steeply banked track with a radius of a kilometer or more.

The generous diameter of such an installation would work to minimize "coriolis" effects of dizziness and disorientation. The Gravitrak would in fact be the ground-based analog of a slice of space settle-ment, achieving the simulation of gravity in exactly the same way. Because this would be done within a host gravity environment, the track would be steeply banked, at an angle, not perpendicular to the axis of angular momentum. See: MMM # 58 SEP '92 pp 3-6 "Xities Serving Asteroid Miners"; [republished in MMMC #6] and MMM # 70 NOV '93 pp 7-8 "Main Belt Service Center on Ceres".[republished in MMMC #7]

We had already suggested that such a ground-based artificial gravity system form the heart of facilities on Phobos, riding the lip of the 5km/3mi wide crater Stickney on an 89°+ banked track at 307 mph (once around in just under 2 minutes or 1/2 rpm) to simulate Mars' 0.38G. [MMM #6 JUN '87 "Mars, PHOBOS, Deimos"][republished in MMMC #1]

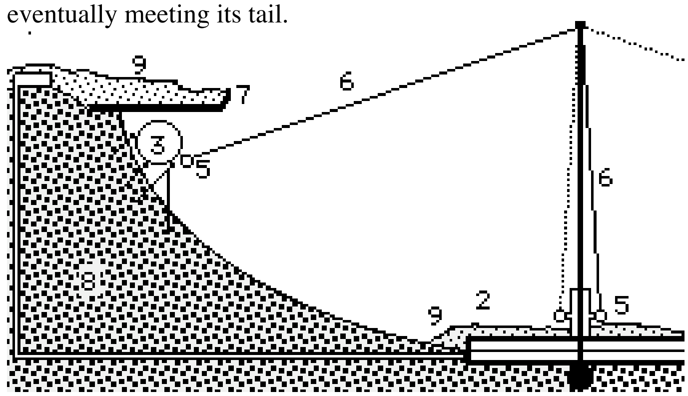
A variably banking transfer vehicle on a side rail would accelerate to meet, then dock with such an "Earth-train", then undock and decelerate to dock with surface-stationary facilities. Alternately, the whole train would periodically spin down, then back up, say every eight hours, to let people on or off. This simpler access option could either present major problems in emergency situations if schedules were followed, or result in some chaos if they were not.



MAGLEV HEXAPOTENCY TRAINING FACILITY SCHEME: Banked track (1, 2) is situated inside the lip of an appropriate-sized crater. 3) Space Frame support for shielding shed; 4) retainer lip; 5) regolith shielding; 6) crater bedrock; 7) maglev torus section module illustrating effective nadir; 8) surface-stationary mini-g facilities in middle of crater.

In the scheme below (the MMM # 70 article), a "Maypole" suspended "taxi-shuttle" is used to give access to a permanently circling Maglev Facility.

The MagLev portion could start with a single car, but as demand and usage rose, could grow by adding cars connected by pressurized vestibules, even to the point of eventually meeting its tail.



KEY: **1** auxiliary crater rim surface facilities, elevator and corridor to **2** main crater bottom natural-G installations. **3** Maglev Habitat areas with 'standard' 1/6th G lunar gravity shown 'riding' two crater slope rails, with third support rail for deceleration to stop for maintenance and adding new modules; **4** "Maypole" pylon and bedrock anchor; **5** counterbalanced pair of shuttle modules (original 'starter' habitat modules prior to building the settlement expansion Maglev habitat facility), shown both at rest docked with main crater bottom facility and at Maglev matching velocity for docking and transfer of personnel especially at shift change; **6** shuttle tethers which lengthen by reeling out as centrifugal force increases; **7** cantilevered shielding retainer lip; **8** undisturbed soil and rock; **9** shielding soil.

A Gravitrak Gym to simulated full Earth gravity would be expensive, unlikely to be installed until the settlement had reached some milestone size. A Maypole type facility would be quite a bit cheaper and attempted on a smaller scale. Two counterbalancing cars would be needed.

Some Lunans will choose to maintain Earth-tone all their lives, even if they never return, just to enjoy the self-assurance that they *could* return if the reason or desire to do so ever arose. Others, feeling no such need, will choose instead to cut the emotional umbilical cord to Earth. And still others will simply surrender any chance of return rather than maintain the needed physical discipline.

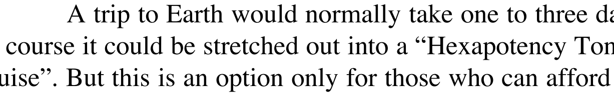
For sure, those who have never been Earth-shape or have long lost former tone and conditioning will have a hard time working against the grain to regain a state of physical "readiness" unnecessary in day in, day out lunar frontier living routines. It will be as difficult, and as much against the grain, as effective dieting and weight management.

For those to whom "hexapotency" is important, fitting muscle and physiological toning into the daily schedule may be as difficult as most Earth people find it to integrate dedicated exercise periods into their own busy lives and changing schedules.

TONING UP FOR MARS

Mars gravity is 3/8ths Earth normal, or about 2 $^1/4$ times Lunar "sixthweight". Lunans who want to help pioneer the Mars Frontier (or go for an extended visit) will need to tone up as well. But this goal can be accomplished on route as the Earth-Moon to Mars trip will be long enough and offer plenty of discretionary time waiting to be structured.

A two-part tether or boom connected transit ship could provide the needed environment naturally by spinning up gradually from simulated lunar to Martian gravity levels. Gym exercises would be extra, meaning that toning for Mars could "take up" no time at all, and leave the traveler 100% free for other diversions and/or fare-lowering assignments.



A trip to Earth would normally take one to three days. Of course it could be stretched out into a "Hexapotency Toning Cruise". But this is an option only for those who can afford the considerable extra time off. <*MMM*>

Details of Lava Tube Formation

by Jim Nieland <jnieland@worldaccessnet.com>

I noted with interest your description of lava tube formation on the web page [page *reference unclear*]. While generally correct, the complexity of lava tube formation is much greater than suggested. We have discovered this in the study of lava caves in Oregon, Washington, and observation of actively developing tubes in Hawaii.

For example, in the tubes we have studied, it appears most are completely filled with lava only during the earliest phases of formation. Very quickly the lava tube floors retreat through a process of thermal erosion; the lava tube equivalent of a stream eroding downward into its channel. This process results in the formation of an open space developing between the surface of flowing lava within the tube and tube roof. This can most easily be observed in active lava tubes in Hawaii where tube evolution can be observed through active skylights. In some caves we have surveyed, thermal erosion can be credited with the development of multileveled lava tubes. This at times has resulted in a vertical extent of over 250 feet, a significant amount of downward cutting by flowing lava.

Entrances to lava tubes come in several forms, collapsed ceilings (sinkholes), skylights (unroofed openings to the surface), and areas of subsidence caused by withdrawal of ponded lava beneath a crust. sinkholes and skylights are the most common.

The patterns that a lava tube exhibit are largely a function of the fluidity of lavas, slope of the land over which flows spread, and the longevity and volume of the flow. There is also a progression in tube configuration based on the age of the tube, and whether it is developed near a spreading margin or in the center of a flow. Near flow margins it is typical for lavas to spread through a complex network of dendritic distribution tubes. In the center of a flow, and particularly near its upper reaches, single supply tubes tend to evolve.

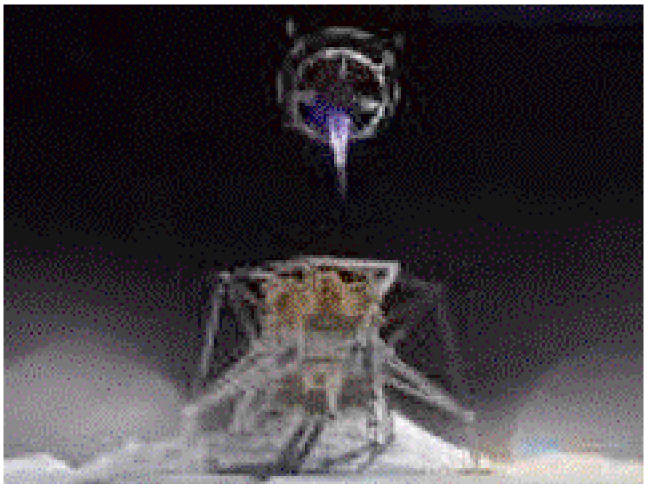
Another interesting aspect of lava tubes is the porosity of the walls, ceiling and floor. When lava cools it shrinks about 1-1.5%. This manifests itself as contraction cracks. If the cracks are close together, stability of the ceiling and walls is compromised, often resulting in collapse which may reach the surface forming an entrance. Wide unsupported ceilings are most vulnerable.

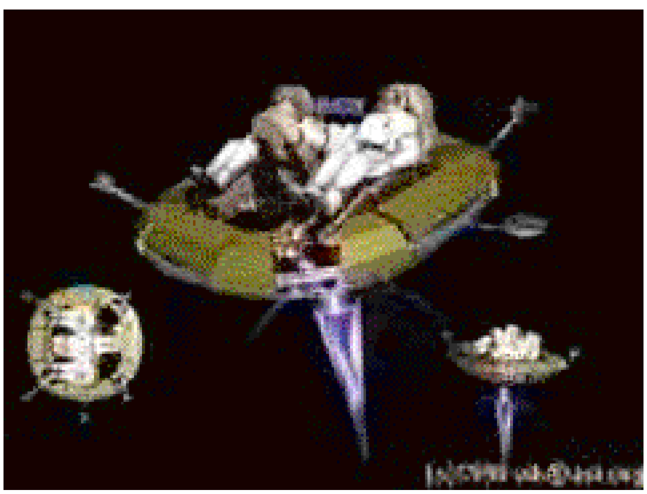
Porous walls and ceilings allow large amounts of air exchange with the outside. This is particularly evident in tubes such as Ape Cave near Mount St. Helens. The mile-long lower cave develops wind velocities at constrictions in excess of 10 MPH. This is impressive since there is no lower entrance and all air must be exchanged through thousands of cracks <*JN*>

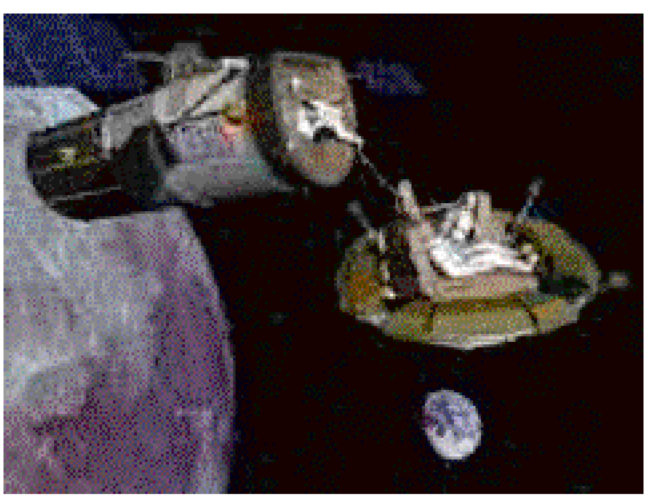
Lunar Ascent Vehicle
of the Artemis Project™

Illustrations by Vik Olliver

This "space motorcycle" is is a minimalist vehicle for returning astronauts from the moon. As the return trip is only a few hours long, it makes sense to leave the habitable portion of the mission on the surface for use next time, and to ascend using suits on a minimal structure. That's what this is, as concieved by Greg Bennett of The Artemis Project™. *Minimalizing the ascent vehicle allows leaving more mass behind, namely the triple SpaceHab habitat module.*



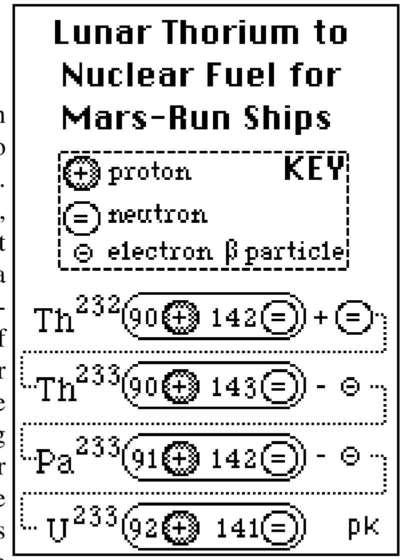




MMM #123 - MAR 1999 - Mars

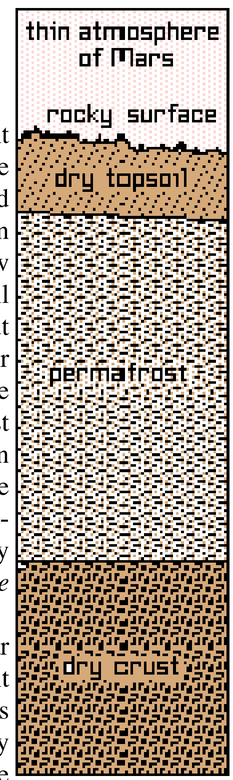
Moon's Thorium May Unlock Gates to Mars

The first human scouts may journey to Mars on chemical rockets. But settlers, developers, tourists, and traders won't be so willing to spend a chunk of their lives getting there, more much if they come back. Nuclear rockets can fix the time problem. But if shipping nuclear fuels through our atmosphere is banned, the only key to the Mars Frontier may lie on the Moon. *See below.*



In Focus First Step toward Mapping Martian Permafrost

There is widespread agreement that the many of the features of the Martian surface show that Mars once had abundant water: rivers, seas, even an ocean. Yet the only trace of water now visible is in the polar ice caps. Did it all evaporate into space? Surely some did, but just as surely, ground water and water saturated soils froze in place. We are likely to find an extensive permafrost layer, continuous in some areas, not so in others, thicker here, thinner there. The actual water content may be vary considerably. Some deposits may be fairly fresh, others rather salty. So we guess. *We need to know!*



Unless we are going to melt polar ice at the fringes of the ice caps and pipe it to lower latitude outposts in aqueducts reminiscent of Lowell's canals, we may need to site our bases in areas where we can tap local permafrost reserves. Several permafrost tap operations are in service here and there on Earth, so this is not an altogether novel idea.

Two Deep Space 2 microprobes are en route to Mars aboard the Mars Polar Lander launched this January. They will crash at about 200 mps (400 mph) burying themselves beneath the surface. They will then sample the soil, looking for signs of water ice.

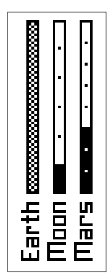
The target site is within the edge of the layered terrain near Mars's south pole. Finding (or not finding) subsurface ice in this location, within a meter of the surface, will neither prove or disprove the existence of globally extensive permafrost. It's a neat and adventurous science experiment. But it won't give us an iota of the knowledge we need. It'd be foolish to await positive results before brainstorming what we have to next.

We have extensive permafrost regions here on Earth in Alaska, Canada, and Siberia. This gives us the opportunity to brainstorm and test remote sensing instruments to detect permafrost and at least partially quantify it by flying a precursor mission in Earth polar orbit. The results would give us great confidence in interpreting any data gathered by a twin probe, subsequently put into Mars polar orbit. We *need* this data!

The Ground-Penetrating Radar Experiment conducted this past summer on Canada's Devon I. (p. 9) is *a major first step*. The goal was to map ground-ice and other subsurface discontinuities in a variety of locations. Distribution and structure of ground-ice was studied. GPR imaging of the subsurface was 'ground-truthed', where possible, with direct drilling. Devon's breccia may be a close physical analog to regolith at high martian latitudes. This GPR test may hint what a similar effort might reveal on Mars. - *PK*

Mars 3/8 the Gravity Enroute to♂ Mars

by Peter Kokh



At million$ per man hour on Mars, does it make sense to guarantee that the first few months will be unproductive due to the need to recuperate from 6-9 months of zero-G when this could be avoided? Maybe, if it saved anything, the trip home could be done in zero-G, jettisoning whatever equipment mass was necessary to provide rotation. But certainly not on the way out.

It is not a question of physiological health. Perhaps we can keep people healthy in zero-G. *That is totally irrelevant*. It is a question of preparedness.

Nor is the other extreme appropriate: sending out our scouts on a ship designed to offer full Earth normal (1G) gravity. Not only would that environment fail to acclimatize them to Mars, it would require 8/3rds or 167% greater boom or tether length *and mass* - at the same rpm rotational speed.

On the way home, Mars gravity would suffice, shortening the period of rehabilitation to full Earth normal gravity. The crew would not need to be fit to hit the ground running, so to speak. They will be on extended debriefing vacation anyway.

Why do many Mars Mission architects not want to bother? Providing for artificial gravity adds some constraint on Mars ship design, adds weight, and adds a modicum of vulnerability. So what? If we don't do it, the quality of the return on the mission investment will, with absolute certainty, be compromised. The savings from not providing artificial gravity does not pass the cost/benefit ratio test!

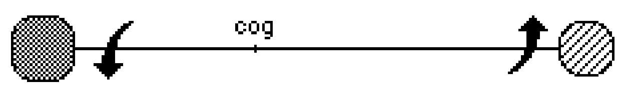
Further, NASA has wasted decades with lip service experimentation with tethers, and no more than paper study experiments with artificial gravity. The agency simply is not ready. It has no reason to feel confident it can pull off an artificial gravity mission. NASA *seems* to have a cultural mental block against the subject. If that is indeed the case, then, if we are to have the best Mars Mission we can for the money, some other agency may have to be put in charge, even if we have to create one.

We are more likely to go back on sequel expeditions of exploration and go on to establish an outpost at which we can experiment with living on Mars on its own terms, preparing for day we can open of Mars as a Frontier for settlement - more likely that is, *if we do the very first mission right*, and as well as we can. If the rubric of the first mission is simply *Marsandback*, one word, then doing it right, *doing it as an overture to the future* - that won't matter. Quite predictably, we will get as minimalist a Mars mission (in the singular) as possible instead. If you think its been a long wait after Apollo for our yet unscheduled Return-to-the-Moon-to-Stay, try staying alive after such a first Mars mission long enough to see the next!

BASIC ARTIFICIAL GRAVITY SCHEME

Many people are familiar with the giant wheel station of Wernher von Braun, well illustrated in the 1968 classic Arthur C. Clarke/Stanley Kubrik film: 2001: A Space Odyssey. Many have also seen artist sketches of Gerard O'Neill's classic space settlement designs: Bernal Sphere (Island I), Stanford Torus (Island II), Sunflower (Island III). The concept is also key to two TV Series: Babylon V and Deep Space 9.

But nothing so grandiose, complex, or vast is needed to effect an artificial gravity environment. All we need is a *pair* of masses, *not necessarily equal,* joined by a tether or boom, and set into a spin about the common center of gravity ["cog"]- like a barbell.



The pertinent questions are:

- How slow/fast should the spin rate be?
- How long/short should the tether or boom be?
- Which is more advantageous, tether or boom?
- How do we deploy to the separated configuration?
- How do we spin up/despin the assembly?
- How do we rejoin the assembly components?
- How can we abort from tether or boom failure?
- What items should go into the Consist of each end?

Their seems to be widespread agreement that a spin rate of 1 rpm is tolerable by most people, and that a spin rate of 2 rpm may be tolerated by enough people to find a crew. Coriolis effects, which cause dizziness when you turn your head, is the problem to be minimized here.

At 2 rpm, the habitat part of the assembly would have to be 581 ft (162 m) from the center of gravity. At 1 rpm, this distance would be 1062 ft (324 m). The distance from the center of gravity ["cog"] of the Counterweight "Consist" (assembly) would depend on its mass relative to that of the Habitat or Crew Consist. The less it weighs, the longer the distance to the cog, just as the less your friend weighs, the further he or she has to sit from the fulcrum of the teeter-totter to balance the load. By the same token, the less the mass of the counter-weight, the greater the total length and mass of the tether. But as the tether or boom should be consi-derably lighter than either of the two counterbalanced portions, the mass fraction of the counter-weight is not a critical concern.

Tethers will be much lighter than booms, and generally easier to deploy (via a simple winch and storage reel). Tests seem to show that a rigid boom is *not* appreciably more stable than a tether, weighs considerably more, and may indeed have *more* failure modes. The concern is to avoid twisting at the end of the tether. If a boom is used, the forces that would build up to induce twist could eventually weaken or even fracture the connection. So it is much better to *reduce the tendency* to twist, than to *try to control* it with fragile rigidity. This can be done with a pair of gyros *counter*-rotating in the plane of overall spin, one inside each assembly. [We have never seen this suggestion made - why not? It need not add much additional mass to either consist, in comparison to all we save by using a tether instead of a boom.]

The two assemblies can be separated with a mechanical shove, the tether being allowed to pay out freely to the set length. Two small rockets, one at each end, vectored slightly outward to counter the bounce-back when the tether limits are reached, fire in opposite directions in the selected plane of spin, just as the tether was reaching full pay out.

When the cruise potion of the journey is over, and preparations must be made to go into orbit about Mars (or Earth), an opposing pair of retro rockets fires in the spinward direction to slow the angular momentum to zero, as the winch reels in the tether.

The tether should not break or snap, the rotational forces being well within its design limits. But the question arises, what if tether should be severed by errant debris or some meteorite? This question has been addressed* but it would seem that the probabilities of this happening, while finite, are astronomically small, and that is the right word.

* "A Manned Mars Artificial Gravity Vehicle", David N. Schultz et alii, pp. 325-352, specifically p.339-343, in The Case for Mars III: Strategies for Exploration, Editor: Carol Stoker, Vol. 74, Science and Technology Series, American Astronautical Soc.

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WHAT ITEMS SHOULD BE AT EITHER END?

This is a question that has no hard and fast answer. There are pros & cons of safety vs. convenience in putting all the habitat crew space at one end, or splitting it up. Most would keep all personnel together, and we agree. The next consideration is which items must be accessible during cruise mode, and which will not be needed until journey's end. If this preliminary sort leaves the non-crew assembly mass being too "light", we could add the expended trans-Mars-injection booster, or we might consider keeping some liquid consumables at that end, accessed as needed through double tubing built into the tether, shifted mass replaced by liquid wastes.

Our next consideration is what type mission are we talking about. A first "Marsandback" mission will need to carry along a landing shuttle and an Earth return vehicle (if not one and the same) if one (or both) had not previously been sent ahead to be awaiting the crew in Mars orbit and/or on the surface. All published Mission Plans that we have seen that work artificial gravity in the design are of this type.

In MMM, we have a habit of looking beyond beginnings. A vehicle carrying pioneers in an era when most stay and relatively few return to Earth, can be designed as a "frog" - amphibious. The crew quarters would be designed to pass through Mars atmosphere, land, and be recycled as *badly needed* surface vehicle, or extra habitat or lab space: "one way to Mars". The Mars-bound assemblies need not include anything needed for crew return. The part of the transit chassis that remains in Mars orbit, could be tugged or barged back to Earth to be reoutfitted with new passenger modules to bring more pioneers.

All the designs I have seen are apparently for chemical fuels. The barbell design is especially right for Nuclear Ships. The large separation between the units will afford added radiation protection for the crew and passengers, the nuclear plant being housed at the opposite end of the boom or tether.

The "cycling" Mars ships proposed by Aldrin and others could be quite large, with permanent artificial gravity designs, plying the Earth-Mars run continually for decades. Design options are many.

Craft bringing Lunans to Mars might start the trip at 1/6th G and gradually work up to 3/8ths G on the first half of the journey, leaving time for Moon-acclimatized people to get used to the heavier load. Another special case has native-born or naturalized Martians traveling to Earth. Again, the journey could start at 3/8ths G and build up gradually to full 1G.

We need to bite the artificial gravity bullet, not just on the drawing boards, but in low Earth-orbit testbed facilities where we can afford trial and error. *This minority view must prevail.*

NOTE: *artificial gravity is NOT a feature of the Mars Direct mission architecture in so far as it incorporates the ARES shuttle-derived vehicle. But that vehicle is not essential to Mars Direct.*

From this point of view, the Mars Direct mission architecture needs to be reviewed. Getting there fast and cheap is no good if you get there physically incapable of performing on Mars itself!

We think that a redesign is possible that would provide Mars level gravity for the trip to Mars.

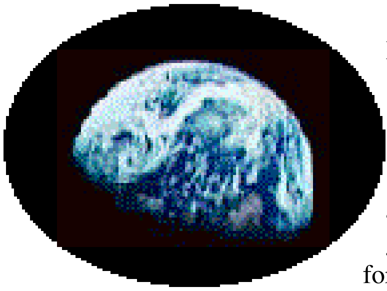
As the return to Earth will be in a different vehicle, that posses a separate question, but one less critical for mission success.

Any "Humans to Mars" Mission Plan that
fails to provide artificial gravity enroute,
is not quite ready to be taken seriously

. - <MMM>

MMM #124 - APR 1999

Live Window Views of Earth



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

In Focus The Precursor Space Economy of Zero/Low Mass Products

Currently all "space" money and/or credits change hands between people living and working on Earth. There is not yet a space economy in the more rigorous sense of people working and/or living in space, i.e. an economy that extends to space because the human community has overflown into space.

Honesty requires us to recognize our impatience to feel we are accomplishing something we are not. *What we now have is precursor activity in which there is a "Space Vector" to what is still an "All-Earth Economy"*.

Yet, the humblest steps of a true space economy may not be that far around the corner. As a trial definition, let's posit that true space economic activity requires a product that at least in part is realized through a man-made or man-arranged activity beyond the atmosphere (involving a satellite or a lander or flyby probe, etc.). Ruled out by our trial definition are money making schemes unofficially naming remote stars after oneself or a loved one for a fee, selling bogus deeds for undeveloped homestead sites on the Moon or Mars, or titles to whole asteroids, etc.

The two undeniably profitable categories of economic activity that come closest to meeting our trial definition are remote sensing and communications satellites. Telecommunications satellites are a multibillion dollar a year business. But they only relay data through space boomerang style. Television , the internet, global cellular telephone calls - these are all commonplaces (or soon to be) of today upon which almost all other economic activities are growing increasingly dependent.

Remote sensing from orbiting satellites and other craft, produces a product in the form of maps from data that is gather-able *only from a space vantage point*. Even if the sale of remote sensing data is not yet profitable, no one can demean the incalculable economic benefits that weather satellites, thematic mappers, navigation satellites, and search & rescue satellites have had on our economy.

Two new categories of space vector business have begun in earnest and promise to grow - vanity products & services, and advertising. Neither is likely to become an enduring billion-dollar business. These kind of services are prone to typical boom & bust of "fads".

Growing Scope of the Space Vanity Business

To date, vanity export products involve low mass cremains (Celestis, Inc. www.celestis.com) and low mass value-added archival records (Applied Space Resources www.millennial-archive.com.) This last endeavor hopes to become real in 2002-3.

Celestis, Inc. hopes to soon offer placement of cremains in long-lasting high orbits, in lunar-impact decay orbits, and aboard craft bound for interstellar space. Calling such endeavors "Vanity" businesses is not a putdown. These are legitimate enterprises that serve a real need, just as do the "Vanity" automobile license plates offered in most states. Not included, because it was a non profit project, is the sending of names of people along on the Stardust comet mission.

Space Vanity Products not yet on the market but certainly economically feasible include solar powered Electronic Advertising & Message Billboards in space locations, *not* intended to be visible to the naked eye by people on Earth's surface, but, for example, viewable online via the web, by relay from a live feed camera locked on the electronic message board on location. A fee could be paid by the viewer to access the message, and/or prepaid by the advertiser or the individual leaving the message. Thus some enterprise could place such a board on the Moon where the associated camera would see it against a striking moonscape. The impact of "I love you, honey! Happy anniversary! - Tom" live from the Moon could be especially endearing, or forgiving, as the need of the occasion may be. Here we have a business plan that should not cost mega-millions. The electronic message board with camera could all be miniaturized into a low mass payload. Anyone with the money is welcome to steal this idea. We have published it previously.

Vanity Remote Manufactures are also potential moneymakers: tele stamped bricks or tiles or panes on the Moon at Apollo Lander Memorial sites - e.g. to be used in a future site visitor's center.

The Entertainment & Amusement Category

Several people have dreamed of landing a small fleet of identical teleoperable rovers on the Moon and sell the rights to race them over a controlled course (pre-programmed to not accept commands to stray from the course boundaries) for a set time slot. Individuals could pay for the privilege or companies could buy slots and offer them as promotional lottery prizes. People have dreamed of doing the same thing on a grander scale with solar sails bound for Mars, for example.

Tourist Experiences

Suborbital hops for paying customers are just around the bend. Tourism will become a real space enterprise - *in our sense* - when there are orbital hotel resorts at which to spend money. - PK

by Peter Kokh

See These Articles from MMM Back Issues

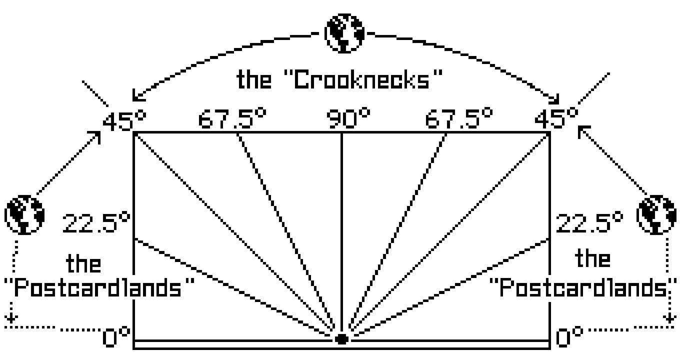
MMM # 69 OCT '93, pp. 8-9, "7 Wonders of the Moon"
MMM #107 JUL '97, pp 3-5, "Earth: Color Medley Calendar in the Moon's Nearside Sky" - republished in MMMC #10

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.

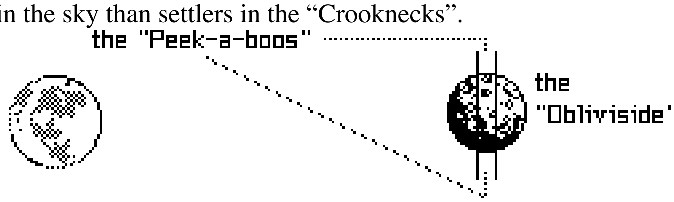
The **"Postcardlands"** are nearside peripheral regions in which the Earth hovers perpetually a comfortable 5-45° above the horizon.

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.

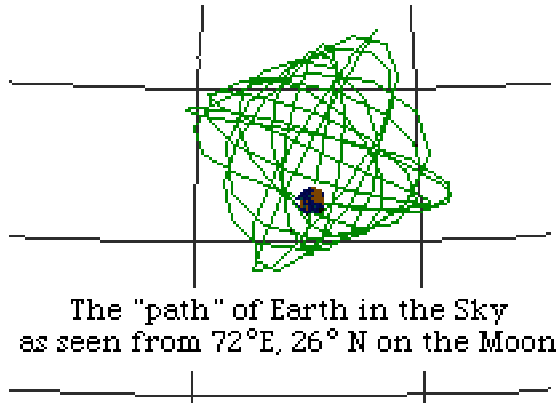


Because of the comfort factor, pioneers living in the "Postcardlands" will be much more aware of Earth's presence in the sky than settlers in the "Crooknecks".



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 moving more than 7° off some anchor point. Windows designed to focus on Earth will have to take this into account.

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.



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.

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 daylit 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, and 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 month-like 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 Mir-type 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.

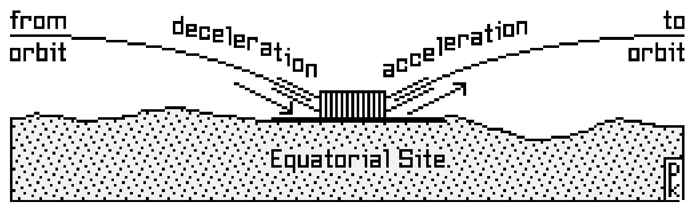
For Profit Opportunities

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>**

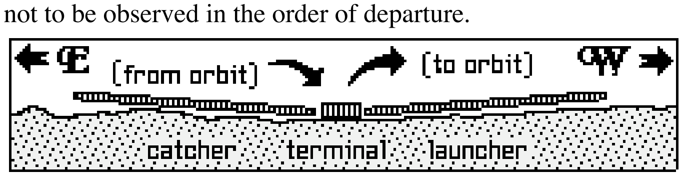
Man-rated Mass Drivers & Mass Catcher to & from Orbit



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.

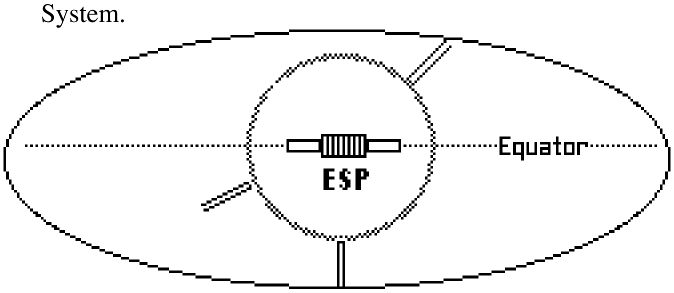


As traffic at this electromagnetic space port (ESP) grows, more parking slips will have to be added and provision for such expansion should be made in the original design.

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 System.



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 on-loading 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 intersettlement 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 pre-history 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 preestablished centers in other areas of the Moon to continue to thrive. More, a Central Interchute Hub need not preclude regional Interchute hubs.

Revenues:

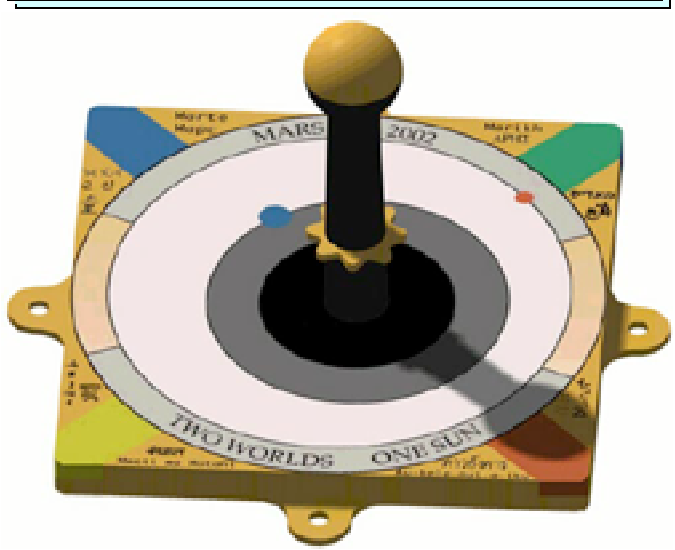
Paying the price tag of an ESP Hub Installation can be handled through Space-line can arrival, departure, parking and transfer (gate) fees, ticket counter leases, corporate hanger leases and user fees, and other "anchor tenant" contracts for companies wanting to provide service to the traffic (hotels, 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>

MMM #125 - MAY 1999



Design of the Web-viewable "Mars Sundial" - on Mars, January 2002

Four bands of color for calibration purposes run outward to each corner: clockwise from bottom left yellow, blue, green, red. The word "Mars" is engraved around the gold edges in 24 languages. A circular band reads "Mars 2002" at the top, and "Two Vehicles, One Sun" at the bottom. Two eccentric circles relate the orbits of Earth and Mars. Blue and red dots show their positions at the time of landing. A golden Sun sits atop the shadow post. Web-watchers on Earth will see the passing of the Martian day in the sweep of the central post shadow in a pattern that changes with the seasons.

In Focus Sundials on Mars & Other Hitchhiker Goodies

http://unisci.com/stories/19992/0422991.htm
[this site has moved]

Bill Nye had an elegant idea. The popular "Science Guy" of PBS fame looked at drawings of the proposed Mars Surveyor 2001 Lander. His eye was caught by a small square and post used as a kind of test pattern to calibrate the craft's color panoramic camera. His imagination saw it transformed to do double duty as a "sundial". A Cornell graduate, Nye contacted University of Washington (Seattle) Prof. Woodruff Sullivan who was instantly interested.

Over the next eight months, with NASA/JPL blessing, Nye and Sullivan put together a team that included artist Jon Lomberg, a creative consultant to the Mauna Kea Center for Astronomy Education, Hawaii; Tyler Nordgren, artist-astronomer at the U.S. Naval Observatory in Flagstaff, AZ; Louis Friedman, executive directory of the Planetary Society; and Cornell U. astronomers Steven Squres and Jim Bell.

The brilliant results of their brainstorming were announced at a recent press conference at Cornell. The new "Martian Standard Time Zone" takes effect in January 2002, when the 3 inch square sundial, designed and assembled at U-Washington, lands on Mars. The redesigned test pattern-sundial will be visible to all of us, thanks to the Internet.

The Mars Sundial will hardly advance Mars Science, and will surely not demonstrate technologies vital to the establishment of a human settlement on Mars. But it will, as did the Mars Pathfinder rover, and as will the Mars Airplane Kitty Hawk, help fix the attention of the public on Mars, and give concrete detail to not quite believable visions of the eventual transformation of Mars to a human world.

The cost will be minimal, both in dollars and in extra payload mass (2 oz.).

That's the elegance of the idea. *Take equipment that must make the trip anyway, and at nominal expense transform it into something that will serve another function with payback in the priceless currency of public support.*

This is not the first example of a payload sent into space aimed at seizing public imagination. The plaques on the Apollo Lunar Landers and the Voyager spacecraft are early examples.

Given Nye's shining example, should we not attempt to make what he did a deliberate and regular process? We can't leave it to the mission scientists and investigators whose attention is properly riveted on scientific investigation. Nor can we leave it to those on the other end of the talent spectrum, who have no understanding of what goes into a payload package.

The whole idea, you see, is to look at - *and understand* - a piece of scientific equipment or a spacecraft part, and be able to envision it performing quite other functions with minimal alterations non-prejudicial to the original purpose of the item. Fortunately, we are blessed with a healthy percentage of technical people who also have strong aptitudes in other areas: art, craft, enterprise, advertising, etc. etc.

Let's brainstorm more such potent hitchhikers!

But does the Mars Sundial exhaust the list of possibilities? Is it a unique opportunity unlikely to come up again? It would be defeatist to assume so. So let's assume the opposite, that there are additional opportunities awaiting the spark of creative genius.

How do we attempt this brainstorming as a regular extra-mission team oversight? We could put together a team of science popularizers, like Nye, who it would seem would have the "right stuff." They would pour over plans for spacecraft, especially planetary landers, that are in the early design process and together or separately use their creative x-ray vision to expose unsuspected opportunities to non-interferingly transform this or that into something that will catch the public imagination.

Or, organizers of individual missions could run design competitions, picking equipment where function does not specify every detail of form. They would be under no obligation to go with a best entry. Nothing suitable might emerge.

The idea is to maximize "hitchhiker options" for **imagination-seizing payloads at nominal cost.** If it pays off in public support that may translate to more and bigger missions, or missions on a faster more frequent pace. The real hope, of course, is that it will pay off for support of future manned missions to follow in the footsteps of our robotic scouts.

Both the Moon and Mars are currently barren worlds of magnificent but discouraging desolation. Anything we can put there that opens the door to the vision of these worlds transformed as theaters of human life takes on heroic value. The Mars Sundial and other familiar human artifacts make strange worlds seem less so, and helps our collective feeble vision take the next giant step.

Do we have any suggestions for similar hitchhiker artifacts? We've talked about the PR value of setting down on the Moon:

- a Beacon visible to the naked eye, and of
- small electronic message billboards on the Moon viewable on the Internet.

But we didn't cast them as redesigns of equipment that would be making the trip anyway. So we can't take credit for similar ideas. Instead, we put the idea, the spark, the challenge, out to all our readers and to the public in general. Hopefully, the Mars Sundial will not be the end of the line. <PK>

A Levittown on the Moon

First Construction and a Look 50 Years Later

[How it could be built soon on the cheap and how it would evolve from canned uniform housing to a highly personalized settlement.]

by Peter Kokh

Granted, most people who see a human future on the Moon, don't see much beyond a science outpost of a few to a few hundred people at best. All attempts to fly a one-product lunar economy have failed, of course, and only serve to demonstrate the economic density of those who have promoted them.

A Diversified Lunar Economy

On Earth, the only "viable" economies are diversified ones. Why should it be any different out there? Given that 90% of most national economies involve production for local consumption, and that exports are needed principally to pay for importing items that cannot yet be produced competitively at home, the three things we need to consider are:

1. local production of as much total product mass as possible intended for local consumption: housing, furnishings, storage, infrastructure items, food, etc. For this end, they have to maximize what they can do with concrete, ceramics, steel, other lunar alloys, glass and glass composites.
2. finding external markets for the same or similar items: in short, anything Lunans can produce for themselves, should be marketable to any other "space market" (installations in LEO, L4 or L5, outfitters for Mars expeditions) at a competitive advantage of equivalent items shipped up Earth's deep fuel-sucking gravity well.
3. producing products and services specifically for external markets

Inflationary Population Growth

On this basis, economic breakeven should be possible, *but only if the Lunar population grows as fast as possible.* What Lunans will be able to produce for themselves at any given time will depend on the size of the labor pool. The more hesitation there is in population expansion, the slower will be the progress towards economic self-sufficiency, and the more prolonged the period of economic vulnerability during which the young settlement risks unrecoverable failure. Lunar settlement will not be for cautious conservative temperaments, but a "do or die" affair.

Constraints on Building Lunar Housing

The greatest product demand by far will be for expansion housing and shelter. The need to use manpower as efficiently as possible means that a properly designed modular housing system will be one that requires an absolute minimum of man hours to put in place and pressurize. Once that stage is reached, enterprising settlers are free to spend a lifetime of after-hours free time finishing the interiors in a fashion that expresses their talents and personalities. There will be a considerable "after-market" demand for part time artists and craftsmen on the Moon.

Aspects of Lunar Architecture & Construction

We have spoken about Lunar Architecture before and recommend rereading the following articles (neither of which are yet posted to the MMM Archives at www.asi.org/mmm - we hope to rectify that within the coming year.)

- MMM #5 May '87 "Lunar Architecture"
- MMM #75 May '94 "Lunar Appropriate Modular Architecture"

In the second article, we defined a "Lunar Appropriate" Modular Architecture as incorporating these six elements:

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

In the same article in MMM #75, we introduced the concept of the lunar "Great Home".

Size of Lunar Homes - the "Great Home" Concept

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

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

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

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

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

Levittown, Long Island, New York: 1947-1999

The recent 50th anniversary celebration for the bold experiment in cheap canned housing that was Levittown brought to our attention a book about the town: "Expanding the American Dream: Building and Rebuilding Levittown" by Barbara M. Kelly, 1993, State University of New York Press, ISBN 0-7914-1287-3 (/1288-1 pbk)/ As I was ten when this venture began, I have been aware of the evolution of Levittown all my life. Might we find in this story templates for a fast-expansion lunar town?

In three short years, over 17,000 Cape Cods and ranch homes, each in 5 versions, were built in Levittown, which today has a population of 55,000. In the post war (WWII) period, the market for housing was very strong and people bought what they could. The homes were inexpensive *starters*. Observers were almost unanimous in predicting that the development would become an instant slum. But they did not count on the resourcefulness and determination of the Levittowners. Over the years they remodeled, rebuilt, customized, and personalized their homes. Today, while you can still see the Cape Cod origins, there is no shortage of diversity and variety.

There was room for built-in expansion in the unfinished attics. Unfortunately, another built-in expansion opportunity was passed over in the desire to keep initial costs low: the homes had no basements. New York building codes must be more lenient than those in Wisconsin!

The lots were generous and the yards large. So eventually people added carports, then transformed these into garages, rebuilt these as family rooms and added new garages, etc. Family Rooms, dens, extra bedrooms, and other special activity rooms were the most popular additions.

The original cost spread of the homes was very small, in the $7,000-$9,000 range in 1947-9 dollars. Each house came with a kitchen, a living room, a bathroom, and two bedrooms - a start on the American Dream.

On the Moon some needs will differ

Owning a home gives people a stake. Nowhere will this be more important than on the Moon, where settlers will have made at least tentative decisions to forsake their Eden-home planet, probably forever. I fault Robert Heinlein's vision in "The Moon is a Harsh Mistress": cramped underground rabbit warrens. On the Moon, lot costs are negligible with as much land as the U.S., Canada, Brazil, and China put together and currently somewhat less than very few people!

Yes, as long as habitat space is pre-manufactured on Earth and brought to the Moon at great expense, people *will have to make do cheek by jowl*. But *once* expansion space can be built from local materials, and constructed in assembly-line fashion, there is no need to be stingy. On the contrary, there are these reasons to make "starter" homes spacious:

1. On the Moon, there is no external biosphere, no shirt-sleeve-friendly outdoors. People *have to put their garden and lawn space indoors*, e.g. in a central atrium. This works well with the on site pretreatment of toilet wastes [cf. MMM #116, pp. 9-11, "A Modular Approach to Biospherics" and http://www.lunar-reclamation.org/page11mm.htm]

2. On the Moon, with high vacuum outside, it will be much more difficult to “add-on” to established pressurized habitats and all the more *reason to include generous unfinished spaces*.
3. On the Moon, it will be especially important to give new stakeholders every *chance to start cottage industries* that eventually will become a strong private industry sector. Expansion space within the “Great Home” will serve as a land grant for such purposes. Those not enterprise-minded can use the space for other purposes.

As on Earth, starter homes will be rebuilt by their owners; there is no such-thing as a standard cookie-cutter family, either in size or in makeup. But people will customize their lunar homes as they have their homes on Earth not only to fit the changing size and evolving makeup of their families but also to express personal tastes in color, style, design, etc. Lunar homes are likely to have customizable façades on the pressurized streetways they front. The rest of the home will be buried in regolith (unless within a lavatube). Even so, some will choose to customize these mounds [MMM #55 MAY ‘92, p 7, “Moon Roofs”].

Lunar settlers need to get settled in large spacious quarters - pressurized, with thermal control, air exchange, electricity, and plumbing. But the interiors do not need to be pre-finished in any other way. All other internal work can be done in whatever degree of labor-intensivity the new settlers are comfortable with. Settlers can be simply granted the deed to these homes in exchange for agreeing to settle, or earn them by finishing a set minimum of the interiors.

Levittown on the Moon? Yes, with these differences. We see no other way. <MMM>

Private Enterprise Means Going Back to Stay!

by Gregory Bennett

[Reprinted with permission from Space Policy Digest, ed. Rick Kolker http://spacepolicy.org/page_gb.html]

"There are three things you want to know about what we're up to," I said, ticking them off on my fingers as I went.

- "We're going back to the Moon.
- "We're doing it as private enterprise.
- "You can come, too!"

And the crowd went wild.

Really! It was the most gratifying response I've had from any audience listening to the Artemis Project pitch. We shouldn't be surprised that this particular audience would grasp the enormous concept of the project in one gulp: I was speaking to the Annual Gathering of Mensans from all over the world.

Among those three points, the real key is doing it as private enterprise. We can do fantastic things with government-sponsored space programs, but not enduring things. Quoting myself:

"Politicians do what politicians do for political reasons."

That's not a condemnation of politics; far from it. We should be glad that politicians don't do things for other than political reasons. Throughout the free world, politics is the tool we use to keep our governments under control. While politics has withstood the test of time for maintaining a measure of control over the behavior of politicians, and has even taken us to the Moon and established a permanent orbiting laboratory, it has not taken us on the path we yearn for.

Politics will never be able to open the boundaries of the realm beyond the sky to everyone who wants to go. Political conditions follow the changing whim of the electorate, and a program to open space as a frontier for settlement by the common man is too long-term a venture to survive constant changes in the political clime.

If we want to go out there to stay, we have to do it as private enterprise. Private enterprise means people are earning a living from it; and that means they'll keep doing it, forever. (Or at least until the sun goes nova. If homo sap has not made it beyond the solar system at that point, the universe will close the book on our species.)

Private enterprise is a slow process. When your daily bread is on the line, you plan carefully, move cautiously. There are business ventures to plan, companies to capitalize. You're not out to impress the world or reduce international tensions; when you do it as private enterprise, your goal is to produce something that other people will value enough that they're willing to pay for it.

We will proceed step-by-step with the program, working our way from one milestone to the next at a pace that seems lethargic compared to the glory days of the Apollo Program. At first, we'll do it just because it's fun to watch. After all, to most folks, space is just another form of entertainment; but hey, there's a lot of money to be earned from entertainment.

Once we've established a foothold on the Moon, we can work on the next stage: actually transporting people to the Moon. This might start with short trips to Earth orbit, three months' salary for a three-hour joy ride. Folks are already working on that part, at least in Japan. Soon though, those ships will go to the Moon, and the industrial infrastructure of the Moon will start to build.

The first trips to the Moon might cost two years' salary, but they will come. Launching 50 paying customers a day, we'll find that we cannot keep up with the demand -- human wealth is expanding faster than we're launching space ships, and people keep making babies. The lunar community will grow to accommodate the demand. They will use the resources of the Moon to build the orbiting hotels that the visionaries of the Fifties could only dream about. They will expand out into mining asteroids; even if they find rich veins of high-grade metal ores on the Moon, they will still need the carbon and hydrogen found in asteroids. With greater demand, the space launch industry will expand and the cost of getting to orbit will plummet.

From the Moon, private enterprise will press on to Mars. With lunar materials for the long-duration spacecraft and the Moon as a launch platform, Mars becomes an attainable goal. If we are lucky, politics will have driven our governments to break the ground for all the technologies needed for the months-long trip between the Moon and Mars, and to survive the incredible cold and unbreathable atmosphere we will encounter there.

After this point, we move beyond the realms of extra-polation into prophecy. Perhaps people will finally build those orbiting habitats the L5 Society was touting back in the 70s. If there is a way to earn a living from it, people will press on to the outer planets and eventually even out to the nearest stars.

Perhaps along the way they will terraform the red planet, as the Mars pundits predict. At this point we have not been able to extrapolate a program that could pay its way through the centuries and millennia that will be required to establish a stable terrestrial environment on Mars. It seems just as likely that our descendants will come up with a much better idea for creating habitable real estate. But that doesn't mean it won't happen, and until the future proves us wrong, it's a very pretty picture.

No matter what hopes you have for yourself and your descendants, if you really want it to happen, look to private enterprise to achieve the goal. You might participate yourself, perhaps only by joining a club and hanging a poster on your wall, or by jumping into the commercial programs with both feet. Whatever you do, you can do so with firm reliance that now that people are building private industries to achieve your goals, it will happen. And you can go, too.

Radar Flashbulbs on the Moon

The Lunar Lavatube Locator Program

by Tom Billings, Project Head

Abstract - This proposal by the Lunar Base Research Team of the Oregon L5 Society is organized, in Schedule and Budget, as a modular program, to bring use of the technology of ground-penetrating radar in incremental steps for exploring the Solar System, to the attention of the research and industrial communities.

It funds a 12 month effort to establish this innovative ground-penetrating radar program. The product will be **a Discovery-class mission proposal**, which will focus on confirming the location of valuable lunar lavatube sites for use as lunar base sites.

Presentations to researchers throughout the twelve months will also bring forward the further use of this technology at asteroids and other bodies lacking substantial liquid water. Use of the techno-logy for examining other subsurface structures and resources will be brought forwards as far as theory will allow, considering the lack of subsurface empirical data from such bodies at present.

The Program Vision

Lavatube caves under the lunar surface will be very useful as lunar base sites. They have left surface indicators that can be found in computerized searches of the Clementine data. A large portion of the targeting data for this program will be acquired by a computer search of the Clementine Lunar Probe's database. Software and hardware for this computer search are now being integrated by volunteers from the Lunar Base Research Team of the Oregon L5 Society and from Lewis & Clark College, and Pacific University, in Oregon. The software was donated by JPL and the Sun Sparc Stations were donated by Mitron Corp. Hardware and software integration assistance is provided by Sun Microsystems.

Lavatube sites that are located should be investigated before commitment to a lunar base there. Ground-penetrating radar images of actual voids at particular sites seem the next step, if images can be obtained cheaply. This proposal describes a program that brings to the research community a combination of technologies to obtain such images of lavatube caves at low incremental cost.

As early as the Apollo Lunar Sounder Experiment, radar has penetrated the Moon to substantial depths. Only soundings were possible given the combination of penetrating wavelengths (1-20 meters) and the aperture of any antenna that could be carried by the Apollo Service Module.

How it would work

Now, operation of the Very Long Baseline Array (VLBA) by NRAO provides a radar aperture that, even from the Earth, could provide a resolution of 20-200 meters at the lunar surface with wavelengths of .5-5.0 meters on the lunar Nearside. Lavatube surface indicators have been found in Apollo photos for caves up to 1100 meters across. But where is the radar energy reflecting off the walls of these lavatube voids to come from?

The 4th power range coefficient in the denominator of the Radar Equation makes this extremely costly if the rf source is on Earth. Likewise, transport to lunar orbit of a powerful rf source is beyond any present budgetary reality. However, if we are investigating only the immediate areas around sites found by the Clementine data search, then a very localized rf source, of appropriate power and wavelength, becomes useful. Such a localized source would give a signal/noise ratio governed by a 2nd power range coefficient in the Radar Equation. This factor, combined with the resolution of the VLBA may make a cheap mission possible.

We would propose that unconventional rf sources can be placed close to some lavatube sites located by lunar surface indicators for far less than an orbiting rf source would cost.

> A free falling object launched from Earth would posses much kinetic energy at the lunar surface. Converting a large portion of that kinetic energy to rf energy is possible with a two-part probe structured as 2 extended concentric metal cylinders that slide past each other when the forward cylinder's end strikes the lunar surface. By allowing a strong magnetic field to brake the rear cylinder's motion, very large electrical currents can be generated in the second cylinder. These large currents would have to be conditioned and turned into appropriate wavelength rf energy, then radiated into the local lunar surface very rapidly.

It is also possible to attain conversion from mechan-ical to electrical energy by compressing electrostatic fields in large capacitors, instead of magnetic fields. Both techniques should be explored in the project.

At a 2.35 km/sec. impact speed, the probe would have less than 1/2000th of a second to "flash" the lunar surface with rf energy before the transmitter and power conditioners at the back of the probe smash into the surface themselves. If it can "flash" successfully, then the rf energy can penetrate the dry lunar surface, reflecting off large discontinuities within the lunar material, including the voids of lavatube caves in the local area.

That rf signal would bounce back to Earth and be picked up by the receivers of the VLBA. Processing of the received signal should allow us to discern which local sites do in fact have lavatube caverns, and characteristics such as overburden, width, depth and length. Presence of local ice and other desirable characteristics might be determined by more sophisticated analysis.

Lunar Mission Options

The mass of the probe will be determined by the energy requirements for penetration at a given wavelength and for reception at the VLBA (Very Long Baseline Array), as well as the total efficiency of conversion from kinetic energy to rf energy. Each probe's "flash" may be able to illuminate strata for a few hundred to a few thousand meters around the probe impact site. This may allow several voids to be confirmed, or even newly found, from one probe. The observation time for the VLBA will be short enough to not intrude much on the normal VLBA observation schedule. This should allow small enough "flashbulb" probes to be sent along with other lunar missions on a "mass-budget available" basis.

If a special lunar mission is set aside for these probes, then timing of individual impacts might be made provisional by selecting a figure-8 trajectory passing close to both Earth and Moon that would return the spacecraft "bus" to a release window once each lunar orbit. Kicking the next small probe out at a slightly different time, with a slightly different push during that window could change the impact point on the Moon and allow a wide range of sites on the Moon to be sampled by these probes. If there is sufficient excess capability available on a commercial comsat launch, then a small package with its own booster might "piggyback" to GTO (Geostationary Transfer Orbit). From there the delta-v requirements for lunar impact are much reduced. Multiple launch opportunities might be available over some years for a continuing program of exploration with this basic flight concept.

For targets away from the easiest Nearside opportunities, several other sensor options become available with more investment in sensor systems. Small free-flying arrays of radar sensors are being proposed for a number of missions, by researchers at both Sandia and Los Alamos. An array of 20 sensor satellites, each massing 15 kg could become available in lunar orbit through the results of recent projects looking at satellite sensor arrays at Sandia and elsewhere. At an altitude of 100 kilometers, an array with a diameter of 10 km. could give a resolution of about 6 meters, with a wavelength of 0.5 meters.

This would require that impact at the surface will happen when the array is overhead in good posi-tion over that particular site. The orbital mechanics of trajectories for impact on the leading limb of the Moon will be easier than any other, but all areas should be reachable. This may dictate that the "bus" for the flashbulbs be placed in highly eccentric lunar orbit, as well as requiring a deorbit thruster to bring each flashbulb to an impact trajectory. Analysis of these orbital trajectories will be begun during this startup of the program.

Other Targets for this technology

This technique may also be applicable to most dry targets in the solar system which have subsurface structures of interest to investigators or investors. Mercury and the moons of Mars are obvious candidates, as is Mars itself, as well as a number of other rocky satellites in the outer solar system.

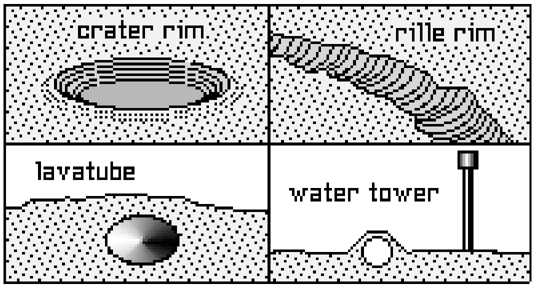
For single targets, there are even smaller sensors being developed in programs like those at Los Alamos. 15 gram sensors that can sense and report the reception of specific burst of radar wavelengths would be spread in an array about 100 km. behind the flashbulb as it falls into the surface. As the reflected burst of rf energy is sensed, each sensor in the array provides both time and amplitude info on appropriate frequencies to a "bus" that dispensed the sensors and tracked their positions. This "bus" then transmits the information back to Earth before the array follows the flashbulb to impact.

An important further application of this technology is in radar penetration of asteroid bodies farther from Earth. These will not be large enough to justify the deployment of a full orbiting array of 15Kg sensor satellites. They would be very interesting for smaller investments, expending only a 10 Kg flashbulb and a 10 Kg "bus" and microsensor array. This would allow structural characteristics of asteroids with non-conductive interiors to be probed, and conductive metallic asteroids to be identified in a definite fashion, at a much lower cost than a rendezvous and landing mission would require.

In speaking to members of the lunar research community, we have found that little effort has been put into lunar ground-penetrating radar in the last 25 years. Unfamiliarity has contributed to doubts. While some have been skeptical about the concept's viability, most have been enthusiastic about pursuing the concept far enough to find out if it will work, or not, for certain. This proposal includes work that should go a long way to dispel doubts about penetration, and signal-noise ratios obtainable.

Project Team:

- Tom Billings - space educator and researcher
- Allen Taylor - Principal Investigator on our project extracting geological features from spacecraft lunar image data. Assoc. Professor at Pacific University, Forest Grove, OR.
- Ed Godshalk - a senior engineer at Maxim Integrated Products in charge of microwave IC package models. He has designed built and delivered 35 Ghz microwave integrated circuit voltage controlled oscillators for the SADARM Project which withstood 20,000 gravities acceleration.
- Bryce Walden - Chair of the Lunar Base Research Team of Oregon L5 Society.
- Cheryl York - Pres. & Treasurer Oregon L5 Society.
- $124,129 Total Budget. Total Time 12 months



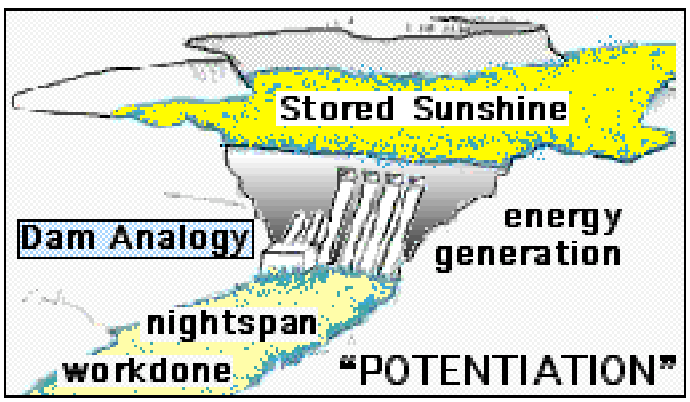
"Heads" for Recirculating Hydroelectric Systems

At right, we see four situations in which there is a high enough "head" even in low lunar gravity, to install a capable "hydroelectric" system on the Moon. Prudently ample water reserves would be pumped to an upper reservoir by solar power during dayspan, then purified by solar ultraviolet under quartz panes. After nightfall, it would be allowed to fall downslope to turbine generators. Details, extras and other ideas for nightspan power:See the article "Potentiation" below.

"Potentiation"

A Strategy for Getting through the Nightspan on the Moon's Own Terms

by Peter Kokh [Presented at ISDC '99, Houston]



Taking Back the Nightspan

On Earth, in many urban areas, there is one special night given over to the assertion of everyone's right to be out and about, safely, at night. "Take back the Night" is aimed at programs that neutralize or reduce nighttime crime and violence that in some areas has frightened people into remaining imprisoned in their homes between sundown and sunup the morning after.

On the Moon, the nightspan is 14.75 days long, 30 times as long as an average terrestrial night. Sunshine is the principal readily tappable local source of energy on the Moon. Its unavailability during nightspan makes the Moon a forbidding place to many people.

If you are one of these, you may need to take a serious look at your pioneer spirit quotient [PSQ]. In every one of the frontiers of the past, pioneers found themselves challenged by the unavailability of various things they had taken for granted in their native homelands. Those who survived, did so by turning to their inner resourcefulness; they "found" ways, not just to make do, but to thrive under. This inventiveness, this eagerness to take on challenges, seems disturbingly lacking in many space-interested people today, the very segment of the population one would expect to be most ready to imagineer their way around every obstacle.

Some of these "discouragees" would rely on nuclear power alone. But if there is a nuclear power plant anywhere on Earth without either planned or unplanned downtime or both, we haven't heard of it. Nuclear is fine - but it can't be relied upon 100% and prudent settlers will have backup power generation capacity. To the extent it will serve genuine settlement, not just a token Kilroy outpost, nuclear has to be "Lunar Nuclear". But more on that later.

Other discouragees just give up and would restrict themselves to a couple of tiny sites at both lunar poles where it is "purported" that "sunlight", always more or less tangential to the surface, is available month around. In fact, the "Peak of Eternal Light" at the south lunar pole enjoys sunlight only 86% of the time with several dark periods. All such spots are inevitably mountain peaks or crater rims, not exactly prime turf upon which to land or erect a base for routine operations.

Some are so intimidated by the lunar nightspan, that they would bypass the Moon altogether in Human expansion into the Solar System.

What we have to say is meant instead for those of you who welcome the challenge of the nightspan. Fully 99.99% of the Moon's surface outside the permashade areas in polar craters experiences alternating two week long dayspans and equally long nightspans. If we are going to "do the Moon", *this is the Moon* we need to do.

We will not earn the right to say we have a permanent human presence on the Moon until we have learned how to deal with the Moon on its own terms. We have to take back the night, the lunar nightspan from the dread bogeyman of the energy desert that tests us. Lunan pioneers with the right stuff will learn not to fear the night, but to love it and cherish is as an equal movement in life's rhythms.

Potential Energy Reservoirs

Potential energy is the reserve energy an object has by virtue of its position in an energy gradient. There are several kinds of "energy hills". All kinds of potential energy reservoirs available on Earth are also available on the Moon. It is up to us to build these various reservoirs, and fill them.

This deliberate effort we dub "potentiation". Potentiation will not only make energy available for the nightspan, it *will* take energy to put in place. And the unlimited solar energy available everywhere on the Moon outside permashaded polar craters is tappable to do the job. The dayspan holds all the keys to the nightspan. But we have to do the right things during dayspan to make our plan work. We have to not only use available solar energy, we must produce a surplus, and store it "uphill". The endless broad and deep river of sunshine can be dammed up. The dams can take various forms of "uphill" holding reservoirs: gravitational, thermal, chemical, angular momentum, and radioactive.

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 mini-biospheres 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, 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.

What about the low lunar gravity? Won't that work against the idea? Well, Niagara Falls, which produces a lot of 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. 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 that involve the use of lavatubes will come with 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 brain-child of Myles A. Mullikin, Lunar Reclamation Society co-founder. 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 occurrs to most people mulling the problem. But it turns out to be very realistic for any kind of outpost or settle-ment. No one pretends the amount of energy stored during dayspan and produced during nightspan by a hydroelectric scheme will meet all the settle-ment'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.

Chemical Energy Stores

If we can use available dayspan solar power to reduce chemical substances into fuels that we can oxidize at night, this would be another way of storing surplus dayspan sunshine. And an especially convenient way at that, for such fuels can run not only static generators, but mobile engines in vehicles.

The polar water ice reserves are, by common expectation, derived from comet volatiles, reaching the Moon by impact, and migrating during the safety of nightspan (in the lee of the dispersing solar wind) to the permanent safety of permanently shaded polar coldtraps. Now comets include large amounts of volatiles other than water. Carbon oxide and nitrogen oxide ices are a major component. We can hope that some of these volatiles will have reached the safety of the polar permashade fields and be found intermixed in the water-ice. The Lunar Prospector team has characterized the polar water ice as relatively pure. But this is with respect to mixed in regolith, not necessarily with respect to other volatiles.

Now the pioneers will need lots of water. But 89% of water by weight is oxygen. As Oxygen makes up 46% of lunar soils by weight, what the pioneers will really need is the polar hydrogen. Shipping water with megatons of included oxygen to settlement sites will be like shipping coals to Newcastle, or ice to Alaska. On the other hand, hydrogen is relatively hard to handle and ship as either liquid or gas.

If the polar reserves include carbon monoxide or carbon dioxide ices, available solar power could be used to refine these ices, reducing them chemically to methane, CH_4. Shipped or piped as either liquid or gas, both the hydrogen and carbon will be most welcome. And combining them with local oxygen (produced from the soil by solar power on site) in fuel cells during the nightspan to produce water, carbon dioxide for the biosphere, and water. The portion of methane arriving during dayspan could accumulate in storage tanks until nightfall. In this way, dayspan sunshine both at the poles and on site is used to produce nightspan-usable fuel and power.

Additionally, methane can be produced in the settle-ment from composted waste biomass., and used as a fuel for motor engines or generators, producing power, water vapor, and carbon dioxide, a necessary component of the settlement atmosphere. "Biogenic" methane will be an important ingre-dient in making the settlement biosphere work - why not also use it to help the settlement through the nightspan?

Electrolysis of on hand water reserves using surplus dayspan sunshine is another way to accumulate and store fuel for nightspan use, namely, oxygen and hydrogen to burn in fuel cells, as we've already mentioned. In short, we need to take the dayspan opportunities out there to charge various types of chemical batteries for nightspan use. This is the simple pioneer virtue of "energy husbandry."

Angular Momentum "slopes"

Large flywheels made of lunar materials, metal alloys or composites, could be placed in small-sized crater bowls for safety. The crater rim slopes would catch any shrapnel if the flywheel's angular momentum exceeded its cohesive strength and disintegrated. Flywheels could also be placed in lavatube voids. During the dayspan, solar electric power could be used to rev up the flywheel. An expandable modular bank of smaller units would combine safety and the ability to store whatever amount of power might be needed.

Thermal slopes & Magma Pools

The Moon is dead geologically speaking. So "geothermal" or selenothermal power is out of the question, right? Not for those with imagination! If there is an early cast basalt industry to provide paving blocks and other low performance items of use to the expanding base, *possibly as a sideline to oxygen production through heating the moon rock*, the excess residual pool of molten regolith produced during the dayspan can be stored in subsurface voids as pools of magma, shielded from the heat-sucking night sky. These holding reservoirs could be lined with refractory materials made on the Moon. The poor thermal conductivity of the regolith overburden will work to conserve the magma pool's heat. How much energy do you need to get through the nightspan? Just melt and store that much regolith as molten magma. This is the vision of Lunar Reclamation Society member-at-large David A. Dunlop, formerly of Green Bay, WI, Oak Park, IL, now in Holland, MI.

As highland regolith generally has a higher melting point than mare regolith, highland regolith can be melted and cast to form a refractory container for mare magma. As we progress further in extracting purified elements, we can improve on this by casting refractory elements out of aluminum oxide.

This regolith melting operation need not be undertaken solely for the purpose of providing a high heat reservoir to tap for nightspan energy. Fused and cast regolith products, specifically cast mare basalt, could provide a whole suite of useful products in the early settlement era, products where high performance is not a requirement: floor and paving tiles and slabs, tableware (dishes), table tops, other furniture items, pots large and small to be used as planter beds, other artifacts, etc.

Cast basalt as a building material and manufacturing stuff may seem exotic. But in fact, there has been a cast basalt industry in central Europe for ages. We need to become familiar with this precedent and take it further, so that when we return to the Moon, we can hit the ground running. Oregon and Hawaii would be good places to practice.

Nader Khalili of the Geltaften Foundation has developed a detailed proposal for casting shelter modules. Casting into a spinning mold would be one simple method of forming conical and hemispheric shapes. Adding crude glass fibers made from highland regolith to the magma mix would provide considerable strength to the finished product.

Magma heat can be used to melt and cast materials with lower melting points, to bend and temper alloys, to glaze ceramics, to crack complex compounds into simpler chemical components, and so on. If this manufacturing activity continued right up to sunset, a leftover magma pool would remain, ready to be used to produce steam to run generators.

There should also be a way to tap the residual heat of recent castings still in the kiln. As magma and castings would slowly cool, it'd seem reasonable to use up the magma heat for electrical generation first, phasing in hydroelectric and fuel cells as the magma pool cooled below the point of usefulness.

Further, magma-generated steam can do more than run generators. Steam can transport heat for baking and curing and heating. Steam can run air compressors and ventilators. Steam can pump water. Steam was once king. Now it is largely forgotten. Lunar pioneers would do well to take a second look.

Mark Reiff suggests another form of lunar heat pump. If vibro-accoustic 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 (e.g. 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.]

Modular Home Solar

At ISDC '98, we spoke of a modular approach to biospherics, designing every lunar habitat and function space to pretreat human wastes generated therein. If we consider that a lunar settlement is not something that will be built all at once, but which may grow and grow, a similar modular approach to providing needed electrical power generation seems appropriate as well.

To some extent it may be possible to do this habitat by habitat for surface settlement structures where dayspan sunshine is available just above the shielding overburden. For lavatube settlements, however, this home by home contribution would not seem feasible. In surface settlement complexes, individual habitats could have solar panels above, designed to catch the sun's rays from the changing angle through the dayspan. This could be either a first or complimentary source of power, reducing the amount that had to be provided by the common settlement grid, and taking the edge off the settlement's growing pains. Such an approach also distributes vulnerability.

We need to seek for practical ways individual habitats could store, and later tap, excess or surplus solar power for nightspan use. On Earth, The Mother Earth News has long taken the lead in helping individual homesteaders to become increasingly self-sufficient and self-reliant. The TMEN spirit provides an invaluable inspiration for future lunar pioneers. Most TMEN-illustrated "appropriate technologies" will not be directly translatable to lunar situations. But the spirit needs to be copied. Hopefully, a Mother Moon News will lead the way in this regard. Indeed, in our own personal dreams, we live long enough to graduate from being editor of ***Moon Miners' Manifesto*** to becoming editor of ***The Mother Moon News***.

"Working Smart" - Operations Engineering

We need to provide electrical power for these nightspan activities: production, work in general, daily living, and recreation. No matter what mix of power generation sources we use for this purpose, and whether or not a nuclear power plant is available as a major part of this mix, there is no escaping the fact that there will ALWAYS be MORE power available during dayspan than nightspan. Why? Because dayspan has available unlimited solar power in addition.

It is unbelievably naive then, to try to plan a lunar economy in which the very same mix of tasks is performed dayspan and nightspan alike without any difference. Here on Earth we are spoiled. *We want to do what we want to do when we feel like doing it*. Hopefully, the lunar pioneers for whom we are paving the way will be a little smarter, and a lot wiser. Lunans will need to "work smart", going through the task load at a pace that goes *with the grain of the host environment*.

This means a simple rhythm that divides the task load, industry by industry, occupation by occupation - *wherever practical* - into one set of more energy-intensive tasks to be accomplished during dayspan, and a second complementary set of energy-light, perhaps more manpower-intensive tasks to be gone through during nightspan.

Lunans will do more production work during dayspan, more maintenance, inventory, packaging, and shipping work during nightspan - again, to the extent feasible. Even here on Earth, some electric utility companies use a two-tiered rate structure to encourage their customers to voluntarily postpone some high-load activities to non-peak usage hours.

On the Moon we are talking about the same thing, on a monthly rather than daily basis, and on a much more extensive scale. It is reasonable that on the Moon electric power to industrial consumers will be priced much higher during nightspan to encourage this type of cooperation. The whole lunar economy will operate as some giant alternator, or as a set of lungs that inhale and exhale.

For manufacturers and others, this means adopting a whole new Philosophy of Operations. It means hiring Operations Managers who are enthused supporters of the new *modus operandi*, rather than those who resist it kicking and screaming.

For workers and others, this task-sorted, polarized operational scheduling will provide a fortnightly change of pace. On the Moon, where there is no changing weather, not even any changing seasons to provide some welcome freshness to life, this bimonthly change of work rhythm will be a psychological bonanza. Those who would insist on running their operations as if dayspan and nightspan made no difference, will find their employees to have lower morale and a greater incidence of psychological and personal problems in comparison.

If some industries have an imbalance, either a preponderance of energy intensive or energy light tasks, they might trade some workers. An energy-intensive casting operation may transfer many of its employees to a sister operation in some industry that has an excess of manpower-intensive, energy light tasks. Such bimonthly change of pace switches might be a much-loved perk for the people involved. Variety is the spice of life. Predictable changes of pace can be salutary and welcome.

It is likely that the load of production and export oriented tasks will still be lower in terms of man-hour needs during nightspan than dayspan. So the two nightspan work weeks could be shorter, either in work hours per day, or in work days per week, or with more generous flextime rules.

Surplus free time could be used for hobbies and/or building up individual cottage industries. Thus the lunar nightspan could be the principal generator of new private enterprises, a wellspring of lunar industrial and economic diversification and continued growth. The domestic economy would be the first beneficiary, but it is inconceivable that new export lines would not emerge from such enterprise.

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.

It's all about learning to live on the Moon, on the Moon's own terms. On Luna, do as the Lunans do! On Earth we have many examples in Nature of plants and animals who have seasonal changing rhythms: squirrels, birds, bears, the list goes on and on. Their daily rhythms adjust to sometimes drastic changes in the environment.

Another analogy is offered in the extreme in bimorphic biological economies, demonstrated by the primitive Hydra, a minute aquatic animal that exists in two quite different alternating generations, the polyp, and the medusa. Similarly, on the Moon, the dayspan economic activity will lead into the nightspan economy which will prepare for the next dayspan and so on indefinitely - two bimorphic generations of one and the same economy.

Lunar Appropriate Nuclear Power

If nuclear power is to be a major player on the Moon, we have to look beyond the dawn period in which ready-to-run nuclear plants are imported from Earth. That's fine for a limited dead-end Antarctic style small outpost which is not expected to grow in its energy requirements. We are not among those inspired by, or envious of the Antarctic achievements. Instead we foresee a continually growing industrial and civilian settlement network on the Moon. And so we look beyond such seemingly lead-nowhere options to a uniquely "lunar-appropriate nuclear power industry". Such an industry would incorporate these features.

(1) The lunar nuclear power plant should burn nuclear fuels produced on the Moon as (a) export of nuclear fuel through Earth's atmosphere may be embargoed by the political successes of those environmental extremists who even now oppose RTG-powered spacecraft to the outer Solar System. And (b) even if this scenario should be successfully avoided, reliance on politically fickle regimes on Earth for sourcing absolutely critical needs, such as nuclear fuels, would mean perpetuating blackmail-inviting dependence upon Earth on the part of settlers.

Lunar Prospector has mapped major Thorium reserves on the Moon. Thorium can be transmuted in lunar fast breeder reactors into fissionable Uranium 233. [see MMM # 123 March '99, pp. 6-7 "Lunar Thorium: Key to Opening up

Mars", and MMM #116 July '98, pp. 7-8 "Uranium & Thorium on the Moon"] Thorium can thus power industrial expansion on the Moon, as well as fuel nuclear ships on the Mars run, without which it is not reasonable to expect the Mars Frontier will ever be opened to settlement.

(2) Nuclear plant engineers and architects need to follow the "**MUS/cle**" paradigm in which the more **M**assive, **U**nitary, **S**imple components are manufactured on the Moon, and only the more sophisticated **c**omplex, **l**ightweight, and **e**lectronic "works" subassemblies are manufactured on Earth. This division of manufacturing labor will work to keep total imported mass low and maximize the lunar contribution for best overall affordability - all while building lunar industrial muscle. All Moon-based industries need to follow this paradigm if the lunar economy is to run in the black.

(3) A standard small "gangable" nuclear plant module must be the goal of this joint MUS/cle design and development process. The modules need to be relatively inexpensive, and manufacturable on demand in quick order, "cle" part on Earth, "MUS" part on the Moon. They need to be functionally gangable into multiple module plants to fit the growing energy demands of quickly expanding settlements as well as small static outposts.

The Moon does have an abundant supply of Helium-3, the ideal fusion fuel. But fusion power has yet to be demonstrated as an engineerable reality.

Other nightspan power solutions frequently proposed are well down the road, something for later generation advanced settlements to consider. These include solar power satellites (the only viable locations not requiring station keeping fuel are L4 and L5 ten times as far from the lunar surface as GEO is from Earth), lunar solar array networks (one over the nearest pole makes the most sense as it would be in sunlight whenever the base is in darkness), and lunar superconducting power storage rings (the prognosis is not good for finding a material producible on the Moon that is superconducting at the temperature of liquid oxygen, the lunar sourceable coolant of choice).

A Tale of Two Cities

Those for whom everything old is worthless, and only *the new* deserves consideration, and those without patience for the inconvenience of having to rethink operations to reschedule them as paired sets of energy-intensive and energy-light tasks that can be performed sequentially, will champion an all nuclear Moon. Let them enjoy their horse blinders.

If we could imagine two identical starter settlements, both in equally favorable sites for local resource-based industrial expansion, but one all nuclear, the other with a healthy reliance on dayspan solar for potentiating nightspan power needs in addition to a nuclear base load, it should be clear that if we revisit them twenty years down the road, it will be no contest which settlement will have grown the most both in population and economic diversity and prosperity.

We need to take a holistic approach to solving energy problems on the Moon. The Moon is a place where we can do precious little as we have been used to doing things on Earth. The Moon is a place where we will be challenged to the utmost in many ways. To be equal to the challenge, we have to examine all the options and hedge all our bets. And, we have to embrace life on the Moon on the Moon's own terms.

As we have taken pains to point out, most of these proposed alternative nightspan energy sources mesh well with the industrial and/or biosphere maintenance needs and goals of the settlement. Even if we have adequate power from a nuke - adequate for the time being anyway - it would be plain stupid not to develop the water reserve-fuel cell cycle, the magma pool-cast basalt cycle, and the methane engine fuel cycles. A settlement that opted not to do so, would court failure.

Conclusion - The Habit of "Energy Husbandry"

In short, if we are going to "do the Moon" we must engage the Moon on its own terms: we have to bite the bullet of dealing with the lunar nightspan head on. Unfortunately, biting the bullet is not a virtue of the predominant space culture. On another issue, writers and visionaries may talk all they want about artificial gravity for space stations and for space vehicles on long journeys. But in industry and agency alike, this is an "unmentionable" by "unspoken" agreement. NASA is in the zero-G rut, comfortable to the point of addiction, deaf and blind to reasons to go beyond this cozy nest.

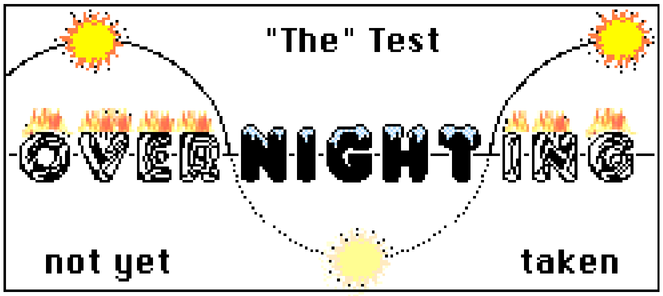
That is one vector of space that the powers that be have no wish to explore. The lunar nightspan is another such vector. We avoided it totally in the Apollo Program - all our landing excursions took place entirely in the local lunar mid-morning timeframe. As NASA does not allow itself to look beyond a limited crew lunar outpost, the idea of a growing flexible power demand can be conveniently pushed back into the nearest closet.

For those of us who have greater dreams, it is absolutely vital that we hitch them to a less tired old horse. We are given, on the Moon, a highly polarized environment. We need to learn how to dam up this overabundant dayspan sunshine so we can tap this reservoir for productive activities all nightspan long. Only then can we boast that "we have arrived" on the Moon, that our presence is "permanent", that we have truly become the adoptive children of this raw unforgiving world, that we have become "Lunans".

Lunans will "husband energy", and learn to mine "energy tailings". In doing so religiously, they will empower themselves not just to "get through" the nightspan, but to producing a "second harvest" from the dayspan sunshine in the process. In time, to Lunans it will have become quite clear that the long nightspan is an asset, not at all the dread liability that today dispirits many. Those who need Earthlike conditions and settings will have to wait a long time before the space economy generates enough wealth to produce them artificially. Meanwhile, pioneers with the right stuff will be ready. **<MMM>**

Relevant Readings from MMM back issues

MMM # 7, JUL '87, "POWERCO"
MMM # 31, DEC '89, pp. 3-5, "Ventures of the Rille People" (Prinzton design study), V. * Multiple Energy Sources.
MMM # 43, MAR '91, pp. 4-5. "NIGHTSPAN"
MMM #90 p. # NOV '95 pp. 7-8 "OVERNIGHTING: Consummating the Marriage of Moon & Base"
Republished in MMM Classics #s 1, 4, 5, 9, and 10]



Dawn Touchdowns, Pre-noon Liftoffs

[from MMM #90 p. NOV '95 pp. 7-8 "Overnighting: Consummating the Marriage of Moon & Base"]

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 full lunar dayspan/nightspan cycle! Here are the figures for each mission.

A 11 TD 10.93 hrs after local sunrise
LO 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 19.52 hrs after local sunrise
(like 6:21-7:01 am on Earth with 6:00 am sunrise)

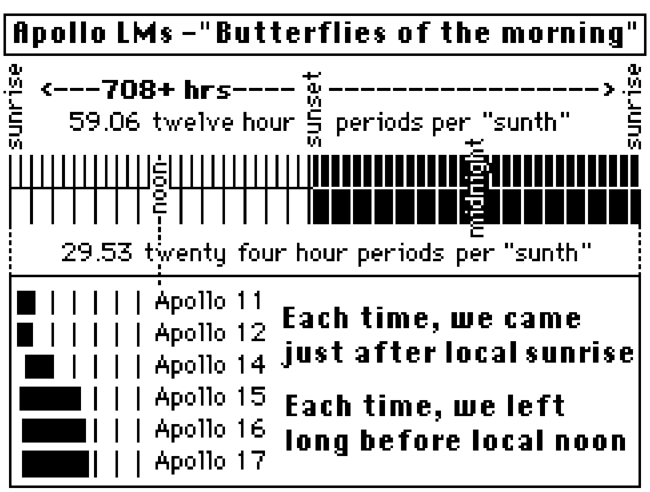
A14 TD 20.75 hrs after local sunrise
LO 33.51 hrs after local sunrise
(like 6:42-7:50 am on Earth with 6:00 am sunrise)

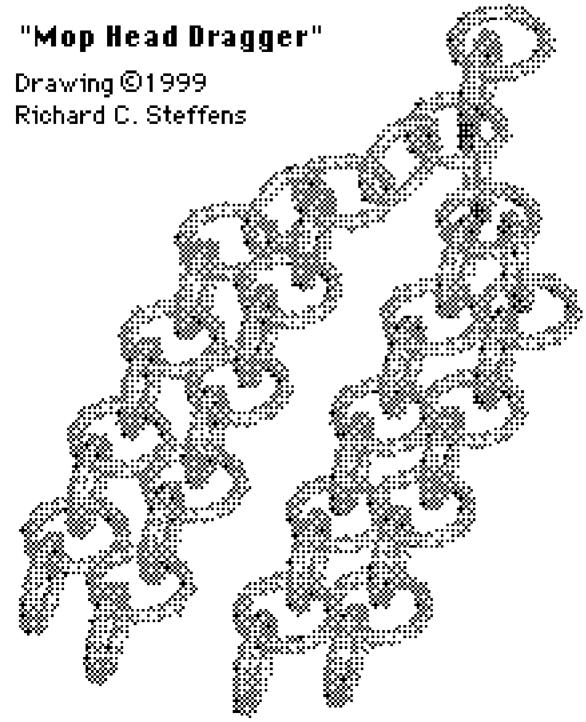
A15 TD 14.04 hrs after local sunrise
LO 68.91 hrs after local sunrise
(like 6:29-8:49 am on Earth with 6:00 am sunrise)

A16 TD 17.82 hrs after local sunrise
LO 71.04 hrs 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 75.00 hrs after local sunrise
(like 6:34-9:06 am on Earth with 6:00 am sunrise)

Sunrise to Sunset: 354.367 hrs = 14.7653 days
Full Sunth (local day): 708.734 hrs = 29.5306 d.





The Dragger
- A Method of Lunar Orbit Insertion

or: The Moon - biggest catch yet
for the big game fisherman.

The Problem:

The high Delta-V of soft landing on the Moon or injecting into orbit around the Moon has been widely cited as an obstacle to space development using lunar resources.

With current technology it is easier to land on Mars than the Moon, despite the fact that Mars is much further away and at the bottom of a deep gravity well. The atmosphere of Mars permits the use of aerobraking to enter Mars orbit, and to decelerate to a subsonic velocity. The Moon, on the other hand, has no atmosphere, so the only way to soft land is by using expensive rockets, or is it ..... ?

The concept of a "dragging grazing trajectory" is believed to be a novel and original concept for addressing this problem. It has the potential of permitting soft landings on the Moon much more cheaply than using rockets. A spacecraft would decelerate from a translunar trajectory by dragging an object along the lunar surface at the end of a tether. Somewhat analogous to a jet landing on an aircraft carrier using an arrester hook.

One of the first applications of this system might be to deliver components for the construction of an electromagnetic mass driver on to the lunar surface.

Mission Description:

The spacecraft travels from Earth to Luna. It takes a grazing trajectory where it approaches close the surface of Luna on its first pass. The perilune [point of orbit closest to the Moon's surface] of the grazing trajectory would be just a few kilometers above the lunar surface. The location of the perilune would be near the center of the far side of the Moon

When the spacecraft enters the region of lunar gravity dominance, about 4500 kilometers [2800 mi.] before perilune, the spacecraft reels out a "dragger" on the end of a long cable approximately 5 to 10 kilometers in length., and achieves a gravity gradient stabilized configuration with respect to the Moon. Just before perilune this dragger then reaches the lunar surface and drags along the lunar dust and decelerates the spacecraft by pulling on the cable.

The amount of deceleration required to achieve initial lunar orbit is remarkably small. If arriving on a minimum energy trajectory from Earth its perilune velocity will be about 2,200 meters/sec. A delta V of 500 meters per second or less is sufficient to leave the spacecraft in an orbit with an apolune [point of orbit furthest from Moon's surface] of about 4,500 km which keeps it within the Moon's gravitational sphere of influence. Navy jets routinely achieve this Delta-V when landing on aircraft carriers.

The initial deceleration window is fairly short. Assuming a 10 km tether and a perilune of 5 km, initial contact will occur about 80 seconds before perilune, and last contact will be about 80 seconds after perilune. In that 40 second period the distance traversed across the lunar surface will be about 320 km. Decelerating 500 m/s in 160 seconds is an average of 0.32 earth gravity equivalent, the peak deceleration depends on the friction force between the dragger and the surface as it encounters ridges, hills and rocks. This can be mitigated by a damping system as described later.

After decelerating by about 500 meters/sec the spacecraft passes perilune and then its altitude increases and it pulls the dragger along with it, losing contact with the lunar surface. Once again it assumes a gravity gradient configuration with respect to the Moon.

At the first apolune after the perilune it would usually perform a small trim burn to raise the perilune by a few tens of kilometers to ensure it does not impact any lunar mountains after the usual orbital mascon drift. Then it would typically coast for a couple of orbits allowing tracking stations or onboard radar to make accurate measurements of the orbit, to plan the next maneuver.

If the spacecraft operator wishes to either lower the apolune or to soft-land on the Moon, then he/she would perform a small retro burn to lower the perilune once again to within a few of kilometers of the surface. Just before the next low perilune the dragger would again contact the lunar surface and slow it some more, perhaps even slow the spacecraft enough to achieve a soft landing (with a couple of trim burns, and a rocket controlled touch down).

Reducing the apolune from the highly elliptical orbit to a circular orbit (i.e. where perilune equals apolune) requires reducing the perilune velocity from about 2,000 m/sec to 1,500 m/sec. This could be done over several orbits.

Final soft landing on the Moon is the most demanding part of the mission. At a perilune altitude of 10 kilometers an orbital velocity of 1500 meters/second must be reduced to zero within about 50 seconds. This is a gee force of three Earth gravities. The time limit of 50 seconds is the time it takes to drop to the lunar surface from 10 kilometers up, landing with an impact speed of 180 meters/sec (400 miles per hour). The dragger can only reduce horizontal velocities, not vertical velocities, so the final 180 m/s vertical component will be counteracted by a rocket engine resulting in a soft landing.

For unmanned payloads an impact velocity of 180 m/s could be accommodated by airbags without the need for rocket engines at all, even human beings could survive this impact with cushioning and/or airbags if the rocket engine failed.

The gee force could be reduced by using a small rocket to counteract the vertical force and thus sustain 5 to 10 kilometer altitude for more than 50 seconds. During 50 seconds decelerating to zero from 1,500 meters/sec the spacecraft will traverse a horizontal distance of 37.5 kilometers [23.3 miles.]. The longer the hover, the more time to permit deceleration and the lower the gee force. Relatively little propellant is needed to sustain a hover and this would reduce the cable weight.

To preserve fuel the cable could be jettisoned once the horizontal velocity is eliminated, so that propellant is not wasted supporting a cable which is no longer of use. After the discarded cable and dragger land on the Moon they would be collected by a robot rover and then launched by a mass driver back towards Earth to be captured and used for future payloads.

The Trade-Off:

We are trading off propellant mass against the mass of the dragger subsystem.

Existing Technology: Aramid yarn (aka Kevlar thread) is very light and strong, and has been used for space tether experiments in Earth orbit. Hence, this is a validated technology. One needs to consider the length of cable needed, and the weight of the deployment mechanism.

Strength and Weight Calculations:

Key properties of Kevlar:

Tensile strength: 400,000 psi

Density: 1.45 g/cc or 90 lb/cu.ft.

At 3 gee deceleration a cable of one square inch cross section can deorbit a payload of 66 tons mass (with no safety factor). The cable would have a mass of 935 kilograms per kilometer or 1.4 % the mass of the payload. A 10 kilometer cable would mass 14% of the payload. The mass of the reel mechanism would be extra. This mass fraction should be compared to on board propellant load to perform a similar mission with rockets.

We want the cable to be as short as possible to reduce weight, this is limited by the accuracy of the guidance system and the topography of the lunar surface. Unfortunately the lunar far side near the perilune is very rugged. We need to research maps of the area to find a fairly smooth area to contact, ideally a straight valley aligned east-west and running for about 100 kilometers.

New Technology:

The morphology of the dragger which is in contact with the lunar surface needs to be studied. Some joint studies by the author and Richard Steffens conceived a configuration of parallel steel chains some hundreds of meters long, held apart by semi rigid spreader bars. [Opening Illustration] Similar in appearance to a fly swatter. The two tips of the first spreader bar would each be attached to separate cables which would be brought together to a common point to which the main 10 km cable would be attached.

Maybe the dragger could be something sacrificial, like the spent last stage of the rocket which launched the spacecraft from Earth, or a string of Moonrocks attached together.

The dragger would convert kinetic energy into heat and would experience a considerable rise in temperature, hence the need to be made of a strong temperature resistant material, steel seems a good choice. The dragger would cool down by radiation.

Issues:

Jerkiness. Big game fishing: hook the Moon and reel it in. Play the Marlin until he is weary then land him. The skills of increasing the tension of the fishing line as the fish wearies, but releasing the line and paying it out when the fish picks up speed and pulls away, are the key art of controlling the tension on the fishing line and preventing it from breaking. Similar methods would be required for controlling the stress in the lunar dragger cable.

The dragger will make intermittent contact with the lunar surface and will bounce off as it hits rocks, hills and craters. This will cause significant variations and spikes in the stress on the cable. Since we want to minimize the cable weight this is a problem, because designing the cable to withstand peak stress transients would make it very heavy. Some means of absorbing the shocks and damping the transients would be required.

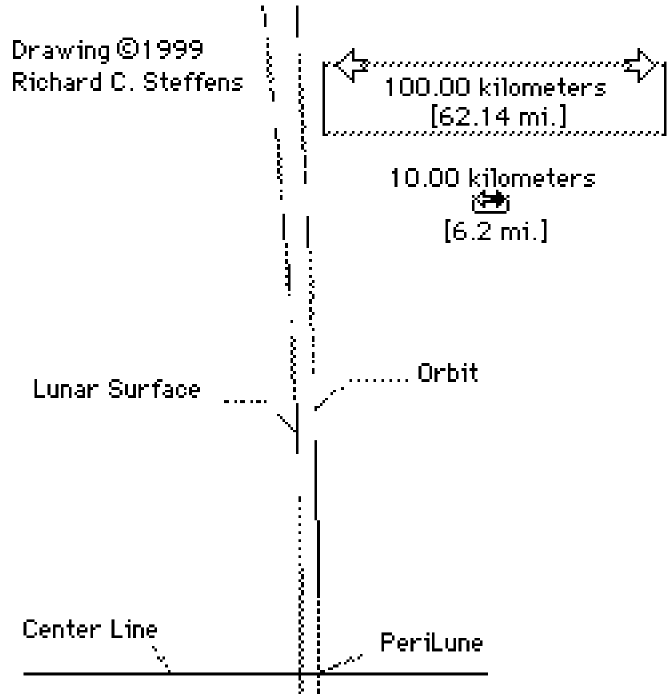
Like big game fishing tackle, the damping system could comprise a pulley-reel attached to the tether cable. When the dragger is initially deployed, only about half the length of cable is reeled out prior to contact. After initial contact, more of the cable is paid out in a slow controlled manner with a variable rate responding to variations in drag force. Acceleration and stress sensors on the spacecraft would increase or decrease the payout rate depending on changes of stress on the cable. If the stress rises it increases the payout rate; if the stress falls it reduces the payout rate or stops paying out completely. Off the shelf computer control systems are easily capable of controlling this process.

The variations of the dragger surface bounces could be averaged out by having several draggers on short cables attached to a spreader bar. Or there may be totally different concepts for the dragger. This is an area where much creativity could be applied.

The actual delta-V achieved by this system would be rather unpredictable because of the unevenness of the lunar surface and variations in the drag stress profile. An intelligent adaptive software based inertial platform could measure the actual delta-V versus a range of reference profiles.

Reusability:

The system does not involve any expendables. The dragger would be a limited life item. Each usage of the dragger would result in erosion, at some point the dragger would cease to be useful. Each dragger would be jettisoned before the payload soft lands but they could be collected and reused.



All artwork in this article are CAD drawings,

About the Author: Charles F. Radley.

Readers of the usenet sci.space.* will be familiar with my postings since 1989, and that I am not a (complete) "crank"

My background includes B.S. Physics, M.S. Systems Engineering, 10+ years aerospace experience. I was a regional director of the National Space society from 1994-5 and have been active in the following NSS Chapters: Ventura County (CA), Cuyahoga Valley Space Society (OH), Oregon-L5; as well as active in the California Space Development Council.

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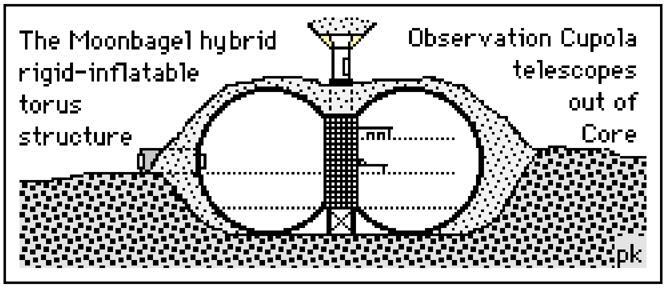
[Ed: Two other equally creative approaches to this problem.

1. Inventor Ed Marwick published and patented [#4,775,120] a low-fuel lunar landing system called “crashportation,” in which payloads are slowed in a landing tube by increasingly dense clouds of moon dust.
2. Kraft Ehricke proposed landing on skis on a very long runway of graded regolith with dig in braking plates to kill velocity.]

A project that isn't difficult, is probably not worth doing!



TransHab™ previewed by Moonbagel™

Above is a sketch of our '91 Moonbagel™ concept for a "hybrid rigid inflatable" structure with real "elbow room" to be deployed on the Moon for first beachhead or as secondary outpost. It is designed to get the maximum volume for the set weight and size constraints of the *cylindrical payload bay* of the Space Shuttle *or of any other launch vehicle*. It clearly prefigures NASA's TransHab™. More just below.

TransHab

The Architecture & Promise of Hybrid Rigid-Inflatables

by Peter Kokh, early proponent of the concept

["**The Lunar Hostel: An Alternative Concept for First Beachhead and Secondary Outposts**" by Peter Kokh, Douglas Armstrong, Mark R. Kaehny and Joseph Susynzki, Proceedings of the Tenth Annual International Space Development Conference, May 23-27, 1991, San Antonio, Texas. Pages 75-92 (SDC 91-021)]

Relevant Back Issue Readings in MMM

The Lunar Hostel paper, printed in its entirety in the Proceedings above, was serialized in MMM, issues #s 48-50; {MMM Classics #5}

plus other relevant readings

MMM # 33 MAR '90 pp. 2-3 "Lawrence Livermore Lab Takes on NASA"

MMM # 48 SEP '91 pp. "Lunar HOSTELS Part I: Amphibious Vehicles"

MMM # 49 OCT '91 pp. 3-6 "Lunar HOSTELS Part II: The Hostel's Share of the Workload"

MMM # 50 NOV '91 pp 6-7, "Lunar HOSTELS: Part III: Some Appropriate Architectures"

MMM # 51 DEC '91, p2 "Hybrid Rigid-Inflatable Structures in Space"; "Camp Millennium Design Competition Proposal"

HARVEST MOON #2 Spr '94 p 3 "The Moonbagel™: A hybrid rigid-inflatable Lunar Beachhead Design that promises generous 'acreage' for farming"

The Problem and the Challenge.

Outpost crews on the Moon or Mars as well as travelers on long duration space voyages or personnel in space stations and other orbital facilities face months-long stays. If they are to do a good job, make effective use of their precious, expensive time, and maintain productively high morale, they will need one thing that, save for Skylab back in the mid-70s, has been absent so far: "**elbow room**" - and lots of it.

The Space Shuttle Payload Bay, as well as the payload farings of existing and proposed unmanned "heavy lifters" share two things in common: tight weight constraints, and a cylindrical volume. The space station habitats of the various ISS international partners all have been designed to live with these constraints, and show it. There seems to be no getting away from the now all too familiar sardine "can".

More generous payload bay space has been on the drawing boards for a long, long time. Without resurrecting the Saturn V, the most promising options are various shuttle derivatives, especially cargo carrying add-ons to the 27.5 ft. wide shuttle External Tank. The ET "Aft Cargo Carrier" has existed on paper for well over a decade, as as various proposed ET topper farings. Length for length, modules designed for the wider ET farings would be over three times as spacious. But even that 27.5 ft. wide diameter would seem to impose limits on elbow room from which it would be nice to be free.

The obvious answer is to design a station or base as a complex of smaller modules, as we have done with Mir, and are attempting to do with ISS. This provides an outpost we can grow into, growing the structure itself as we go along. It requires multiple flights and space-suited assembly in an unforgiving and difficult vacuum environment.

For Mars expeditions, there seems to be a hard choice between:

- a single direct, Earth-surface-to-Mars-surface shot with a space station-sized crew habitat

- a long wait for a post-shuttle vehicle with a wider payload bay and a heavier lifting capacity
- an expensive orbital assembly process - the very von-Braunesque/SEI trap that most let's-open-the-Mars-frontier advocates would like to avoid

On Mars especially, where mission opportunities come 25 plus months apart, it would seem crucial not only to provide elbow room on the surface from the gitgo, but to be able to have it en route, so that the crew does not arrive on the scene psychologically debilitated by "caged-rat syndrome".

For post-beachhead Moon and Mars outposts, we can take the long view and look for larger settlements-in-the-making built on the spot from modules made of building materials produced from local regolith soils. The question is how do we get from the sardine-can present to the spacious future.

How about "Inflatables"?

Back in the late eighties, Lowell Wood of Lawrence Livermore National Laboratory (California) proposed an alternative architecture to the current S.S. Freedom designs and design philosophy. For much less money, he argued, you could deploy a much more spacious space station made out of inflatable modules. Two things popped this balloon:

- inflatables capable of maintaining pressure in space with all the mircometeorites and man-made debris floating around seemed an unproved concept at best, and dangerously foolhardy at worst - there had been no tests of an inflatable fabric or an inflatable fabric sandwich under conditions simulating such an environment
- such inflatables would have to be fully outfitted in space and this would require even more man-hours out in space suits than the worst-case prognosis for Freedom type designs

So Wood's ideas were generally dismissed, no let's-see-what-happens tests conducted, planned, or even considered by NASA. A few space advocates continued to play around with inflatable concepts. And, to its credit, NASA-JSC did try to integrate an inflatable into its Moonbase architecture, a spherical multi-story inflatable to be protected from the harsh elements by regolith-filled bags piled around and on top, igloo style. This provided elbow-room but again, required extensive post-inflation outfitting, making for a complex and riskier deployment.

But, with Congress adamantly averse to even hearing the word "Moon" no real R&D was done on inflatable fabrics. "Inflatables" seemed to be DOA.

Enter Copernicus Construction Company

Copernicus Construction Company is no more than the whimsical name we in the Lunar Reclamation Society picked to refer to our "Define & Design" fun-activity brainstorming group. In the fall and winter of 1988-89, against expected fierce heavyweight competition from groups like Seattle L5's Boeing-laden SLuGS [Seattle Lunar Group Studies], we had decided to enter the National Space Society's Space Habitat Design Competition: Category - Lunar Base for 1,000-5,000 people. Our three-village settlement built within a rille and dubbed tongue-in-cheek "Prinzton" for its site near the crater Prinz (SE of Aristarchus) came in second. (The winning proposal did not satisfy all the design criteria, but was that of a single architectural student and therefore a more fitting recipient of the $2,000 prize.) Eight people from the chapter worked on Prinzton.

As an encore, four of us worked on a paper for presentation at the International Space Development Conference in San Antonio in 1991, two years later. The hook of our paper was the concept of the "hostel", a "big dumb volume" which could function as a complete lunar outpost when and for as long as an "amphibious" (space/surface) crew cabin, dubbed a "Frog." Our idea here was to earn multiple savings:

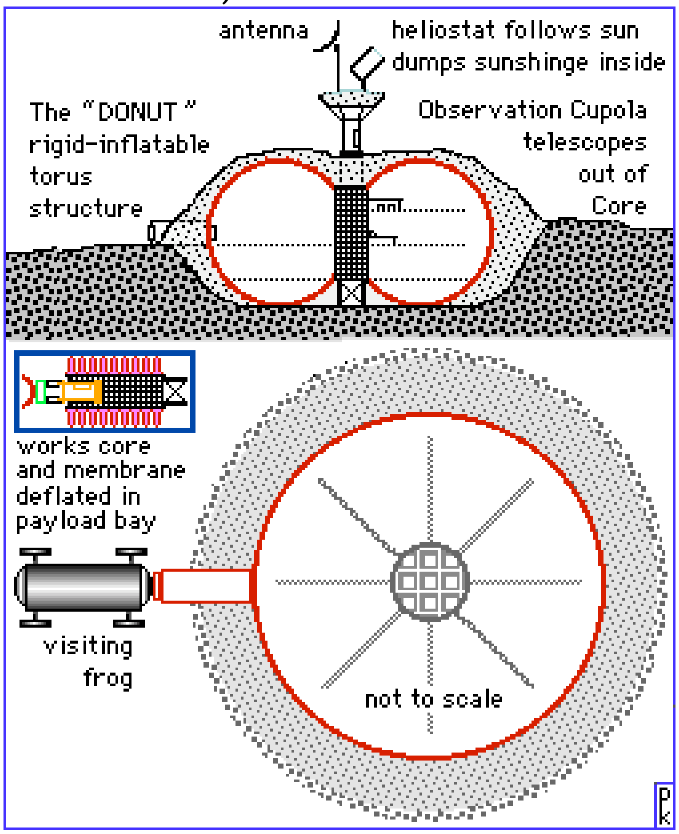
- The lunar ferry would be designed with its crew cabin underslung beneath the main platform between the engines, with the fuel tanks on top. On landing, the crew cabin would winch down to the surface, it's built in mobile chassis deployed, and then taxi over to the outpost site [Note: this concept, outlined in the published San Antonio paper, has since popped up in NASA drawings]
- At the sight, already teledeployed and shielded, would be some kind of "big dumb volume", a pressure-holding container with a dock
- The amphibious frog would already possess all the systems needed to maintain human life: air and water recycling and conditioning, thermal controls, communications, first aid/medical, computer work stations, etc. etc. Why duplicate them expensively in a sometimes unmanned habitat structure, when the latter could enjoy them when the frog was docked with it?
- We carefully separated "functions" which were best assigned to the "Frog" and those best assigned to the "Hostel"

This "define-what-it-is-we're talking-about" work behind us, we began brainstorming ways to provide that "Big Dumb Volume". Half a dozen architectural approaches were sketched out in the paper:

- An all-rigid telescoping can-within-a-can - [NOTE that a recent NASA sketch of a lunar lander has an "extra" room telescoping out of the cabin once the craft is on the lunar surface]
- A rigid-inflatable "sandwich" in which the ceiling and floor, both pre-outfitted with pop-out, pull-down, pull-out, pull-up features are joined by inflatable walls
- A rigid-inflatable "slinky" in which two works-packed open-ended cans are joined by an inflatable cylinder ribbed with a helical systems-conduit providing plug-in-anywhere communications and electrical chases
- A hinged-three-part floor which would open flat with an inflatable "quonset" structure above, the pressure ingeniously reinforcing the stay-flat floor by means of over-pressurized bags alternating right/left 2/3rds hinged sections
- A "donut" inflatable torus that pops out of the walls of a "hexagonal works-packed" rigid cylindrical structure in the donut "hole". It was this TransHab prefiguring hybrid

rigid-inflatable architecture that seemed to us to be the most promising way to get the most out of the shape/ weight constraints of the Shuttle payload bay - or of an External Tank Aft Cargo Carrier etc.

"Donut" Model Hybrid Lunar Surface Base



The "donut" could be loaded with pull-out built-in features: top-mount central solar, visual, and EVA access, side-wall vehicle docking port, decking parts brought up in the core module's "basement', and a peripheral jogging track. The inner surface of the outer side wall could be pre-painted or printed with a 360° panoramic mural medley of Earthscapes and Moonscapes.

Two extra coupling ports in the outer wall at 120° angles we would make possible 'benzene ring' clusters of individual donut units for open-ended "organic molecular" expansion potential.

Small conventional instrument-packed can modules brought up from Earth and coupled at unused ports would allow endless upgrades.

- A sixth architecture, dubbed the "trilobite" was fleshed out after the paper was sent to the San Antonio conference Proceedings, but was printed with the serializing of the paper in MMM. In this design, the cylindrical works-core is designed to be deployed on its side, instead of vertically, with twin inflatable cylinders being deployed out of lockers on either side.
- Also post San Antonio, several rigid-inflatable applications for use in space stations and deep space vehicles were sketched out in MMM # 51

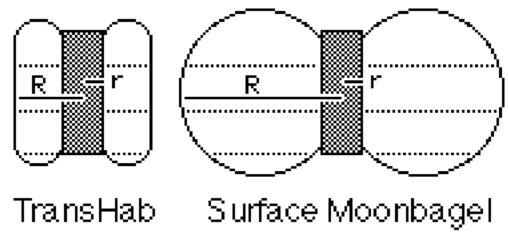
The "donut" has since been more aptly dubbed "the Moonbagel" by LRS at-large member David A. Dunlop. The concept of a vertical works-core tailor-made for a cylindrical payload bay and pre-integrated with an inflatable sidewall torus seemed elegant. Previous writers dealing with inflatables commonly described spheres and cylinders. But on a gravid surface either needed to be stabilized upright - they were *per se* prone to roll. The torus, however had *four considerable and unique advantages:*

1. a wide, extremely stable footprint
2. a generous weight distribution
3. the lowest possible overall profile or height, a very important consideration when considering how to apply regolith-derived shielding
4. together with an integrated works-packed core module, it came pre-outfitted, ready to occupy

As we were interested in the concept first and foremost for lunar (or Martian) surface (or intra-lavatube) applications where there would be no post-deployment exposure either to ultraviolet or micro-meteorites, we did not address the need to "armor" the inflatable wall through layering. We realized, of course, that that would have to be addressed before analogous structures could be deployed in space station or deep space transit situations.

We also did not feel the need to land a pre-deployed structure (we imagined the structure being landed on legs attached to the base of the rigid core module [not to the inflated torus as in the PM illustration at the start of this article], then inflated, then occupied.) This, however, is just the more difficult application for which NASA-JSC has now developed the same architecture. For a human Mars expedition, we need elbow room not only on the surface after the crew arrives, but in transit from Earth to Mars, simply because the journey will be several months long, not just a few days. So the JSC team brainstormed a structure that would be both a better "Transit Habitat" [thus TransHab] and a lighter weight Mars Hab module. Elegant!

Yet this "amphibious" requirement has had its design result both in constraining the radius of the inflatable envelope and in the banding of its outer wall to a flattened shape, somewhat like a tire tread. TransHab's resulting shape and volume is considerably more modest than what that possible for a structure deployed only after landing. Thus the volume multiplier (ratio of its full inflated size to available payload bay space) is held to just under "three" times that offered by a conventional rigid module designed to fit the same payload space. Without the "transit" (especially through Mars' atmosphere) there is no intrinsic reason that this multiplier couldn't be as great as 150! (The formula is pR^2 - pr^2 see illustration:)



Whether someone at JSC had read or heard of our San Antonio paper firsthand, secondhand (the appearance in NASA planning of two other seminal concepts from the same paper would lead one to expect this) or not at all, does not really matter. The "PROBLEM" which we started off to address must sooner or later be obvious to anyone who looks at the situation long and hard, and the solution we came up with is in the end equally "obvious," at least in retrospect. Throughout history, obvious engineering solutions have been independently "invented" by two or more persons or teams on many occasions.

When I toured the NASA TransHab facility at Johnson Space Center on May 29th this year (1999) while at NSS's ISDC in Houston *(thanks to Jerry Smith for the free ticket - Sorry, you couldn't make it Shirley!),* I was filled with a deep excitement to see that our concept was being vindicated by the TransHab engineering team and that many of the design challenges we anticipated had been successfully worked out with practical engineering solutions. After all, we had neither the expertise, nor the resources to further elaborate our seminal concept further.

Indeed, we had wanted somehow to find the money to conduct a national design competition to flush out engineering options to these various design challenges that our paper left untackled. The "Camp Millennium" contest would have had several entry divisions based on sets of problems to be tackled and the various applications (general habitat, laboratory, construction camp, farming pod, hotel/motel, etc.) .

Finding this money was one of several drivers behind LRS' bid to host the 1998 ISDC in Milwaukee. By the time we had realized the needed up front funds to organize and promote the competition as well as the principal prizes, the TransHab team had already nearly completed much of the task. That there is more work to be done we discuss below.

Competition, yes! For just an "inflatable," no!

One of the considerations that has divided the space community over TransHab is the feeling that "any new habitat space to be added to the Space Station should be commercially supplied." We have no quarrel with that assertion. Indeed we in LRS wholeheartedly support that as a requirement.

At the same time, it needs saying *loudly* that it is likely that most such objectors have paid no attention to the architecture of TransHab itself. It is *not* just an inflatable. Its virtues spring from it being a **Hybrid Rigid-Inflatable** designed to make the most of the shuttle's payload bay capacity, as well as to be fully outfitted. These are two virtues that neither Lowell Wood's nor Willey Sadeh's inflatable architectures appear to have exhibited.

On the other hand, NASA could require both these needs to be addressed in any submitted bids. It would not be surprising if in such a situation, our "donut" architecture would be the principal feature of several, if not most serious bids. One thing is sure - other engineering solutions would be flushed out. Quite possibly some would be better and/or cheaper than those found by the Transhab team. That is the whole virtue of honest competition!

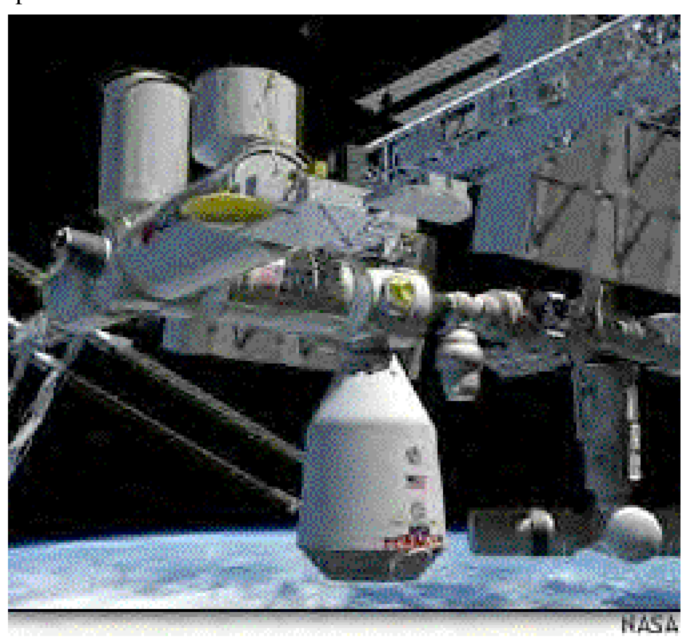
Life-or-death considerations?

Whether the TransHab team is allowed to continue (and finish) its work or not, should not be a matter of life-or-death to any space enthusiast, whether the foreseen application is as a space station expansion module, a transit habitat to Mars doubling as a Mars surface station, a spacious cycling cruise ship habitat area, a habitat deployed within a lunar lavatube or covered with regolith out on the surface. The basic architecture is sufficiently self-evident and elegant as a solution to a general problem that is likely to exist for some time to come.

If the TransHab team had not "invented" this particular hybrid rigid-inflatable architecture (or at least made it their own by all their work), it would inevitably have appeared sooner or later nonetheless. It is too logical an idea for any shortsightedness or objection to the way it is pursued to "nip it in the bud". It can't be "outlawed". It will spring up again.

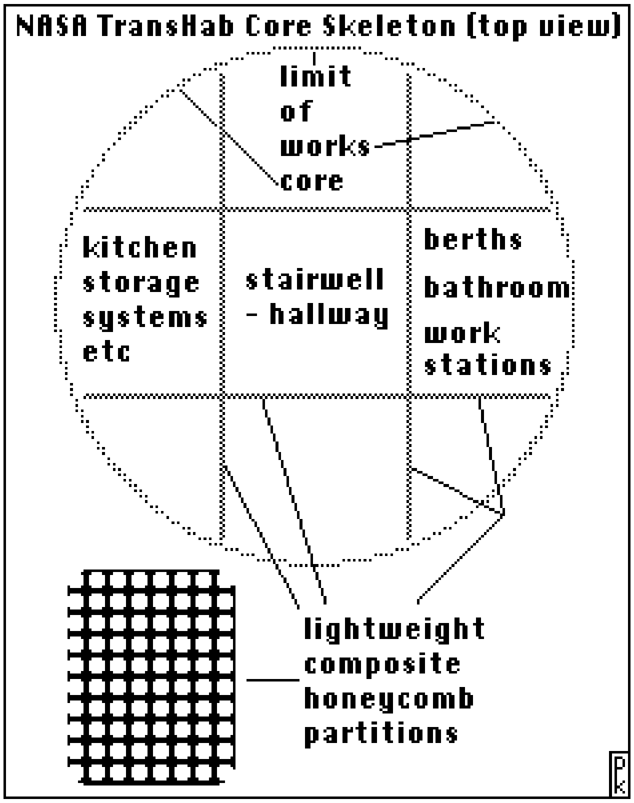
In the light of the Administration's (and Congress's) strong desire that NASA not address a Humans to Mars expedition until the endlessly beleaguered International Space Station is finally a completed reality, the TransHab team had to find another funding home and rationale to continue its research and development. Whether it was Donna Fender's idea, Dan Goldin's or someone else's does not matter. Proposing it as a possible addition to ISS or even as a replacement for the conventional Boeing habitat module already under construction proved to be ill-fated. Leaving the name "TransHab" with its telltale connection with the Humans to Mars program did not help. But perhaps it was all they could do to buy themselves more time and finish the R&D, an indisputable NASA mandate function.

In our opinion, it is a good turn of events that the TransHab effort got as far as it did, and that a great many of the critical key concepts have been validated and engineering solutions found. This R&D provides the essential platform for the entrepreneur to step in. In this sense, if the pro-space objectors to the TransHab project would have rather the project not been begun by NASA, or at least have not been allowed to get this far, they would only have shot our shared commercial space dreams in the foot.



A NASA-JSC illustration of an ISS version of TransHab attached to the space station. The evident teardrop shape seems to this writer to have been a case of artistic license that makes no sense at all and implies that a hard shell had been added.

The idea of testing out the Mars Habitat as conceived by Robert Zubrin by attaching a prototype to the Space Station as a commercially supplied hotel module was proposed several years ago by fellow Wisconsin space activist extraordinaire George French (the man behind the Moonlink™ educational program linked to the Lunar Prospector Mission.) <MMM>



Below: the short, 1-story TransHab prototype at JSC

Up Close and Personal

"The Moon I had known all my life, that two-dimensional, small disk in the sky, has gone away somewhere to be replaced by the most awesome sphere I have ever seen.

It is huge, completely filling our window. And it is three-dimensional."

- Michael Collins, Apollo 11 Command Module

MMM #128 – SEP 1999

[Once "Enough People" are Living & Working in Space, on the Moon, or Mars, "the question" will no longer be so easily brushed aside.]

Defining "Home Rule" for Settlers on the Space Frontier

A Preamble -- to the Discussion

by Peter Kokh

Discussing the Political Future and possible Political Regimes under which settlements on the Moon or Mars, or in space itself can grow and thrive on the Space Frontier is a dangerous question. It would seem to be one big can of worms.

This is one area in which emotion, temperament, and upbringing often have much more to do with our "worldviews" and expectations than does reason or thoughtful discourse. Any sort of consensus seems remote.

We space supporters come from all political persuasions. Not all of us are Republican, though those who are seem to think so. Not all of us are libertarian anarchists, though those who are seem to think so. Not all of us take it for granted that all of space should be annexed to the United States, new state by new state. But those who do seem to think so.

Once there is a critical mass of pioneers on the space frontier, they'll inevitably decide their own future, and the political conditions under which they will live.

I am sure that supporters, in Britain, France, Spain, and Portugal, of the opening of the New World of the Americas, took it for granted that their own national flags would rule forever. They were wrong, and the ultra-patriots amongst us need to take heed. Once (if ever, you sniff) there is a critical mass of pioneers on the space frontier, they will inevitably decide their own future, and the charters or constitutions under which they will live.

To American Patriots who would make the Moon, or a hemisphere of it, the 51st state, we need only remind them that this would make our own Founding Fathers, who fought so hard to free themselves from the British Crown, turn over in their graves. Nothing could be more Un-American at its core, than this so-called American solution.

But why, you ask, would governments on Earth put so much money into "colonies", if they knew that they would one day become free? First easy answer is that they are, fortunately for the settlers, too naive to realize this, or think it can be prevented by Enlightened Paternalism. But those who do take the long view will see this support as hopefully paying off in the creation of viable new markets and stable new trading partners that will benefit the homeland.

Whoa! Let's back up a bit! We may never get that far in space. Sure an outpost or too, and some industry, but enough people to make viable nations? We have enough of this ridiculously nonviable little island nation nonsense in the U.N. as it is!

Well, we broached the "ultimate solution" case of independence -- only to show the direction down which this discussion is meant to take the first halting steps. Let's leave for the future what only the future can decide. But that some sort of decision of this sort may someday be inevitable must be kept in mind, as we take first steps.

The First Step: Defining the Conditions, Stages, and Thresholds of Increasing Levels of Settlement Home Rule

Now there's a more pragmatic frame to the questions we propose to discuss - hopefully with considerable input from our readers - in the next issue or two (or however, long it takes) of Moon Miners' Manifesto.

What I am calling for is a discussion that will advance a consensus on what language should be included in a Civilian Enterprise-based Settlement Charter. I was in my twenties when the European "Colonies" in Africa and Asia achieved their independence. I was living in England in 1960-1 when the British Home Secretary was charged by the government with coming up with intricate home rule arrangements that "protected" the European Settlers and guaranteed them a voice, even though they were most often a small minority. Some of the resulting agreements were most complex, anything but straight forward. I was a studious observer of it all. And to this day, I remain a firm believer that a horrendous amount of trouble and strife can be avoided by the up front design and adoption of Settlement Charters which spell out how "home rule" "will be automatically granted" in a "step by step fashion" "as listed thresholds" of economic and institutional development and of population and economic growth are reached.

If these thresholds are never met, then so what? Everyone knows what the rules are, everyone agrees to them. Political uncertainty is greatly alleviated and in such a climate, economic investment and development, and individual and community planning and life-decisions can be best made. <PK>

A Reusable Lunar ferry

A Flexible Design Concept

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To save vehicle development costs, one basic type of lunar ferry (possibly also used for LEO - Lunar Orbit transit without landing gear) should be developed. The modular vehicle should be able to:

1. land cargo for the base and return to lunar orbit without refueling (before the oxygen plant is running). In this case, extra oxygen tanks replace part of the available cargo pallet space.
2. NORMAL OPERATION (after the oxygen plant is running). In this case the ferry refuels Hydrogen in lunar orbit, lands, refuels Oxygen from the base, returns to lunar orbit where the cycle continues. Oxygen received at the base is used to take off, and also to land. Hydrogen received in orbit is used to land, and also to take off.
3. land extra heavy cargo by being linked together in tandem and operating at least 2 or 4 ferries as a single unit. Ferries should be able to be linked together without a lot of EVA work, and should use active mechanical linkages to lock the vehicles together.
4. carry LOX back into Lunar orbit for use by the LEO-lunar vehicles.
5. 1 + 3 to land heavy cargo before the oxygen plant is ready.

If a non-reusable ferry vehicle is developed first, the design and development costs would be doubled over the cost of a single design. In addition, the expendable ferries would not be available for reuse, parts, or for emergencies. A case could be made for building a few large expendable ferries for landing large items for the base, but using a modular ferry design removes this requirement.

An analysis of maximum required cargo weights and dimensions would allow definition of the optimum ferry size. An initial design decision must be whether 2, 4, or more ferries can be linked. If the individual vehicles are considered as being 4 sided, a 2 ferry system involves a linkage on 1 side of each vehicle, a 4 ferry system means 2 adjoining sides linked per vehicle, and so forth.

Critical questions for such a design would include:

- redundant systems in case the propulsion for a single ferry failed (making composite vehicle attitude control while boosting impossible).
- Linking the electronic controls for each ferry into the composite.
- either designing the landing legs not to interfere with each other, or to allow some central legs to be removed temporarily. (This might require an unacceptably high amount of EVA time and difficulty).

One solution might be entire modular vehicle sides including legs.

- EVA time analysis for linking and unlinking vehicles, and ways to reduce this to an absolute minimum.
- Having a private company design, build, and operate the lunar ferry (as a space transportation service) is strongly recommended.
- Such a ferry design would save development costs and increase the flexibility of the system.
- It would increase the maximum unit payload capacity of the system and the total number of vehicles available.
- It would support early use of lunar derived LOX for ferry fuel. <JS>

Justification for Early Operation of a Lunar Mining Facility

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In order to justify building a lunar base, immediate payback goals should be included in the base plan, as well as longer term payback from lunar and astronomical science. These short term paybacks primarily involve using the moon of a source of raw materials that are already 95% "in space" in terms of launch energy requirements. They include:

1. **Early production of liquid Oxygen** for (1) direct and immediate refueling of the reusable lunar ferry vehicles using lunar oxygen and terrestrial Hydrogen; (2) propulsion use in low and high Earth orbit and for transit between Earth and the Moon; (3) oxygen supplies for the lunar base and in-space air supplies; (4) react with Hydrogen (from Earth) for lunar and in-space water supplies.
2. **Early production of structural materials** (Silica and metals) for (1) truss (lightweight beam assemblies) for the Solar Power Satellite system; (2) lunar base structures.
3. **Silicon for SPS solar array.**

The main point is that functioning "prototype" equipment sized to produce enough LOX to support base construction flights should already be in a advanced stage of perfection by the time of the first base construction landings. If there are any questions about certain phases of a process, small test packages could even be carried on pre-base landings to prove out the technology, or it could be tested in a 1/6 g centrifuge adjacent to the space station. The advanced prototype would be designed to operate semiautonomously, requiring only the attachment of solar foil and addition of lunar regolith. The main advantage over the robot Mars fuel factories proposed by Robert Zubrin is that repairs could be made if necessary, but the design could be similar.

The units would be landed early in the base construction sequence. We could then expect production of LOX to begin fairly soon after base construc-tion starts, and the LOX supply would assist in the completion of the base, as well as in bringing in additional cargos for science and additional habitat modules. This would greatly reduce the costs of bringing propellants from Earth, since the LOX is almost 90 percent of the propellant weight if Hydrogen is used as the fuel.

Later in the base construction the segments of mass drivers and or smelters would be landed. These would depend on the decisions made earlier on the type of lunar derived structural materials to be used for the Solar Power Satellites and/or for lunar structures. The bulk of these would probably be glass/glass composites such as those currently being developed, and the metals aluminum, iron, magnesium, titanium, and perhaps calcium. **<JS>**

Life!
Surprisingly Everywhere!
Everywhere Surprising!

Cost Effectiveness of LEO Staging Base vs. ISS For Moonbound Craft

http://www.asi.org/adb/04/01/01/08/iss-cost-effectiveness.html

by Gregory R. Bennett

Until we've done a detailed cost analysis, we really won't know for sure whether it's less expensive to use the space station or to build an assembly fixture in a low-inclination orbit. We do lose about 10,000 lbs of payload to go to that higher-inclination orbit, but we have to weigh that against the cost of the assembly fixture. Using the Titan IV launcher, it looks like we'd have enough payload margin to rendezvous with the station anyway.

The big cost driver is launch. With launch costs coming down, we might anticipate that the development cost for a new LEO facility could become significant, even one as simple as the facility we've envisioned.

Another big driver is the cost of getting *anything* certified to approach the International Space Station. Several commercial space flight companies have looked into using the ISS as a base for their operations, only to find that they would have to spend more money certifying their spacecraft to operate in the vicinity of the ISS than they spent on developing and operating their craft. This tends to drive commercial space flight to use other facilities, to the detriment of the International Space Station program.

The International Space Station is still a very attractive option since it comes with so many resources, including the potential for earning some money by using the LTV as a laboratory or free-flying servicing vehicle based at the station between moon flights. One of its best features is that it allows our crew to loiter in Earth orbit almost indefinitely if they run into a glitch while assembling the moon vehicle.

We haven't even asked NASA yet whether they like this idea, so nothing is decided. With Mr. Goldin saying things like, "I wish commercial enterprise would be more commercial" we might expect that NASA would want to be very accommodating toward commercial space flight. However this does not appear to be the case. This is the sort of help NASA and the International Partners could provide without having to ask the taxpayers for the money to do something really cool in space; but they're not doing it. Yet. [Updated 8/1/99]

Tell-Tale Signs of SETI Messages

According to statements on the SETI Institute Web site, www.seti.org, "The main feature distinguishing signals produced by a transmitter from those produced by natural processes is their spectral width," that is, how much room on the radio dial they take up.

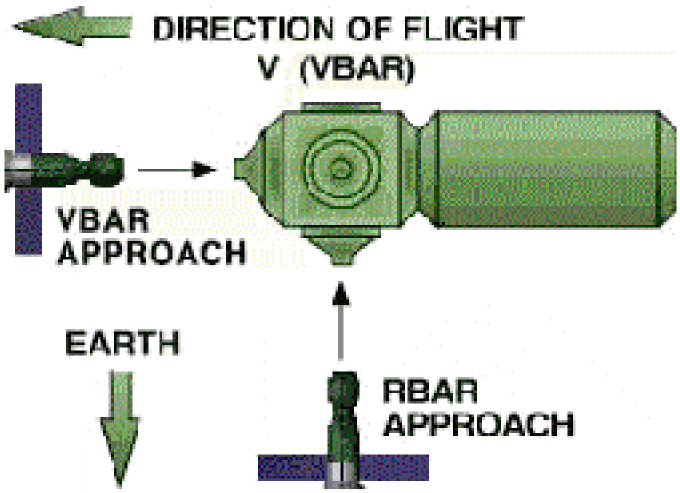
As far as scientists know, **any signal less than about 300 hertz wide is artificially produced.**

Rendezvous Paths to the LEO Staging Base

http://www.asi.org/adb/04/01/01/08/design-considerations.html

by Gregory R. Bennett

The best places to put docking ports in the assembly fixture are at the front and bottom of the little space station. Docking ports in these locations accommodate rendezvous techniques developed over the years.



Rendezvous Direction

The preferred rendezvous approach is along the positive V-bar vector. That means the approaching spacecraft will be coming up on the facility from in front of it, along its velocity vector. (Velocity vector points toward the space station's direction of travel as it orbits around the Earth.)

Second choice would be an R-bar approach. For an R-bar approach, the spacecraft will come up from below, along the radius between the target and the earth's center of gravity. R-bar is a little bit tricky because if you're not at the same altitude as the facility, you'll tend to drift ahead of it (if approaching from below) or behind (if approaching from above).

At the Mir, the Russians often come in along the V-bar or R-bar, and dock at a temporary location. Then they move the spacecraft to its final position with their manual remote manipulator arm.

Gravity Gradient

In designing the LEO Assembly Fixture, keep the gravity gradient in mind. The longest axis of the facility will want to point at the Earth. That gives you a clue as to what orientation this thing will fly, and hence which part of the space station will be pointed toward Earth and which part will be pointed along the velocity vector.

We can control the attitude of the space station to defy the gravity gradient, but this requires using fuel to balance out the forces. It's not a lot of fuel, but over the life of the space station we could add a significant amount to our resupply requirements by fighting gravity. We probably will be better off designing the little space station to go along with Mother Nature. [Updated 8/1/99]

MMM #129 - OCT 1999

[CONTINUING A NEW MMM SERIES: Once “Enough People” are Living & Working in Space, on the Moon, or Mars, “The Question” will demand answering.]

THE HOME RULE QUE$TION

by Peter Kokh

Origins of Civilian Rule & a Domestic Economy

First let us say that this discussion is not about the political evolution of “Company Town” settlements. Some see that as the logical, perhaps the only logical situation. I have seen company towns, and the overwhelming majority of them are not healthy places to live no matter how well maintained. It is important that we work to put in place a regime by which all towns are civilian. The best way to do this is by ensuring that towns are begun as multi-party joint ventures, in no one board room’s pocket.

- Earth-Moon transportation companies
- mining companies
- materials processing companies
- construction companies
- communications companies
- power utilities
- export-import companies etc.

It would seem more of a stretch of imagination to believe that one and only one company will be all these things than to expect that opening the lunar frontier will be a synergistic affair between several. Even if there is a joint venture between several of the companies involved, there will also be subcontractors and then, Voilà - a civilian situation.

If there is more than one company in town, individuals will have some bargaining power. It will be logical to create a civilian authority separate from any and all companies (not necessarily resistant to pressure) to maintain civil order and regulate the interactions of individuals, some employed here, some there. There would be a constable of sorts and a judicial administrator at least. Some decisions could be teleju-dicated from Earth, but that won’t sit well for long. Even if civilian authorities are appointed by powers on Earth, once there services are needed on a regular basis, it is likely they will be living on the Moon and part of the settlement.

Civilian Authority is not necessarily home rule

This by itself is not quite “home rule” - in fact, civilian or not, authority may be quite colonial at first, not even consulting local residents, though that will inexorably invite trouble. The sponsoring national powers on Earth will have their agreed upon policies, (no marriages, no private owner-ship, etc.) many of them favoring the big companies involved. Resentment of one such policy or another may be the first seed of a drive for more resident responsive government. A resident advisory council is a cheap fix sure to be tried first. The recommendations of an advisory council can be ignored, or met with promises there is no intent to keep. The council would serve its purpose of allowing pioneers to vent off steam and frustrations. But it's a foot in the door.

From such beginnings there would seem to be many milestones on the road to "home rule"

- elected advisory representatives
- elected legislative representatives
- elected executive (mayor, governor)
- local courts

While these are the obvious milestones, do not forget how important a factor a bureaucracy can be with life of its own, even in advanced independent democracies such as our own. It would be most efficient for companies to operate in a paperless fashion on the Moon, exporting all desk work electronically to "cheaper" help Earthside.

This saves people on the Moon for the more productive and constructive tasks and will accelerate the growth of the local economy instead of acting as a drag. But once the settlement is big enough to take over such chores, you can see that it might become an issue, not that local bureaucrats will prove to be anymore responsive and helpful than absentee ones.

What "Home Rule" is and isn't

Home Rule is not independence. The American states have more than home rule. They have sovereignty of a sort. But they are not each independent, they share independence. Puerto Rico has home rule. It can govern its own schools, decide what language will be the currency of public business, pass its own laws, do anything at all except print money and have a military or conduct foreign affairs.

In Robert A. Heinlein's ***"The Moon is a Harsh Mistress"*** and Ben Bova's ***"Millennium"*** early lunar outposts went straight for independence. Logically there are intermediate steps, and a steady progress from one through the next is in everyone's interest. Look at what happened to African and other colonies which were summarily freed without preparation and establishment of a sufficient set of local institutions.

The Critical Question

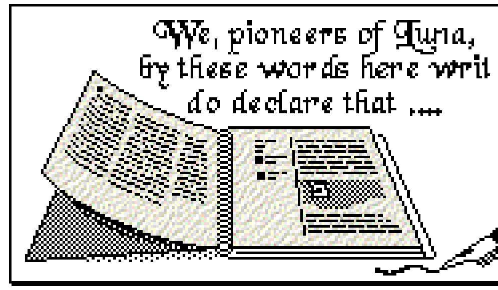
The question is this.

- □ Should this process be left to chance, perhaps in the hope it will never happen, or that the settlement will never amount to much? Or ....
- □ Should we agree upfront on an anmmendable course of progress with ever greater degrees of home rule granted as the settlement reached pre-agreed goals of population growth, economic and industrial diversification, effective self-sufficiency in education and health care, so many months stockpiles of critical reserves of parts, fuels, food, etc., such and such progress towards break-even between exports and imports?

We've seen untold strife in the 60's and since because of the lack of such pre-agreements. We need not make that mistake on the Moon, Mars or anywhere else. <MMM>

We, pioneers of Luna,
in these words here writ,
do declare that ....

A Pre-Settlement Charter for the Moon?



by Peter Kokh

A Lunar Constitution is quite a ways down the road. What we are proposing is to prepare a trial "pre-settlement charter" for any prospective outpost that could conceivably become a full-fledged settle-ment, spelling out stages of "activation" by which "x" amount of growth and "y" steps of achievement will be rewarded by increasing degrees of local control.

Outposts *will* hopefully be in the plural. And if they are, they will be like seeds sown elsewhere. Some will fall on barren ground, fail to germinate or sprout, and become ghost towns. Others will sprout up but not flower. A few may self-propagate into full fledged settlements, even becoming real cities. Is this unrealistic? We think not.

Those who demand that lunar settlements justify their existence on the basis of "one product" before we consent to proceed further without the government holding our hand and picking up the tab, are proposing a test that has been demanded of no settlement before. [We think of Gordon Woodcock's pessimistic assessment of lunar industrial potential a few years back as well as of the NSS challenge for papers for ISDC 2000 which seems to buy into several unjustified and unmentioned assumptions. Engineers and lawyers make good money, not good economics.]

Ninety percent of any economy is domestic, powered by the production of goods and services for local consumption. Would it have made sense to hold up the ships bound for the Americas unless the would-be pioneers could first prove that they had one and only one product in mind that they could make in the New World and export back to England or Spain in enough quantity to earn shipment back to them of *all* their needs and supplies? That is the a priori test some would apply to any commercial for-profit lunar enterprise. It is best just to ignore it, not trying to prove what they cannot understand. Just do it.

Back to that ninety percent. Of the remaining exported sum of goods and services, another ninety percent will be to other space markets (not unlike U.S. to Canada and other North and South American nations as opposed to mother England). The lunar economy will grow apace with the economy in LEO and perhaps apace of efforts to tap asteroid resources and efforts to open the Martian Frontier. *Only the combined space economy as a whole must pay its way* with a positive trade balance with Earth. And in that equation, LEO is part of the space economy. With terracing and step by step industrial and commercial diversification, we see no reason why the Moon itself cannot someday support a population of hundreds of thousands, or more. In contrast, those who forget (or never learned) how economies are put together can only foresee highly subsidized outposts of a few dozen people at best. And the extent of their activism is to get "George" Government to pick up the tab.

Charters for a Plurality of Settlements

Already some will have realized that we must address two questions, not one.

1. When should an outpost on the road to becoming a settlement be granted how much local rule, and
2. When does the entity we are dealing with cease to be individual settlements and become a self organizing frontier association of settlements?

My suggestion a few years back that indepen-dence was something that should be considered only for a multi-setllement frontier that by virtue of its plurality had put itself on the road to global occupa-tion of the Moon or Mars was greeted with derision by Jim Davidson. But in the light of all the unviable island entities we have recently welcomed into the United Nations, is this an unreasonable standard?

It is much less likely that stand-alone lunar settle-ments could achieve economic self-sufficiency than a coopera-tive interdependent, intertrading association of settlements. That's just common sense.

In the ranks of space activism, we have always had a strong anarchist-libertarian constituency for whom space is attractive primarily *because* it opens up the possibility of just such a proliferation of small independent worldlet principalities thumbing their noses and right middle fingers at the rest of the universe and at economic reality. Historically, how-ever, dictatorship becomes more likely in proportion to the economic absurdity involved. Big does not always mean tyranny. Small doesn't always guarantee freedom. The settlers will decide this issue for them-selves. It is not ours to get hot and bothered about.

On Earth, "one world" and "one world govern-ment" are seen as the only rational option by some, and as the most diabolical of solutions by others. But here individual nations and tribes have history and inertia. On the Moon or Mars, where we are "starting over, starting fresh", and where the enemy may be off-planet rather than on, the pioneers will find themselves free to take a second, no baggage look.

Higher goals and economic reality

Meanwhile it makes sense for us to encourage settlements and outposts to seek economic viability in association with one another, not separately. A properly defined and terraced (sequenced) set of milestones defined in a charter agreement will reach a level of demand that may be very difficult (though not impossible) for a solitary settlement to reach, but within the easier, timelier grasp of a cooperative association of settlements. Two examples:

- a full-fledged university
- a major hospital

That the settlement(s) will be both education-ally and medically self-sufficient are reasonable standards for higher levels of "home rule" activation.

In todays world, which is getting ever more complex, it is estimated it takes a city of a quarter million people to produce 95% of its own needs. On the other hand, it is not necessary to produce all your own needs, only to produce enough to sell to earn the money with which to buy everything else.

It is reasonable for the sponsoring powers and agencies to demand attainment of a certain demonstrated level of sustainable economic viability, before agreeing to remove *all* supervision and over-sight. Even today, many nations must surrender the exercise of certain sovereign prerogatives to meet the demands of World Bank lenders. Actually, "indepen-dence" is an illusion. As the economies of all nations continue to globalize, "inter"dependence is what we enjoy, whether we wish to admit it or not.

Back to the Question:

Do we begrudge the pioneers their political autonomy, fighting them every step of the way, thus forcing them to win their rights in a test of power, management-union style? Some, by temperament and prejudice, will prefer, counsel, and demand such a strategy in the hopes of securing financial self-interest as long as possible, delaying the inevitable..

OR, do we lay out a roadmap, locate the mile-stones, and declare the rewards of attaining each. If the proper role of government is to provide a fair set of rules and a level playing field on which all free persons can pursue "life, liberty, and the pursuit of happiness" without further interference, then such "roadmap charters" with staged phases of automatic home rule activation fall within that enlightened mandate. Brainstorming the possible particulars, the forks in the roads, and what prere-quisites must be met for each higher stage of home rule is a project in which I invite all interested readers to participate.

If we leave this to government, we guarantee a non-sensical result. Nothing rational can be produced when political compromise over nongermane issues is the prevailing standard of agreement. That is why we have a shuttle that is less capable than it could be, and are getting a station of similar mongrel breed.

Nor is it in the proven area of demonstrated corporate talents to come up with such documents. This must be the work of a pioneering people. We who would prepare the way for the actual pioneers, are those pioneering people. We must do it, or it will not be done, with the chaos of anarchy the likely result.

A word to contrary minds

We have asked a question, and we know that many will answer in the negative. Those who identify with company management may tend to see the pioneers as employees and consider "home rule" measures as something they should have to bargain for in a test of wills and power. As one who has spent many years in industry, I feel that the arrogance of management is the principal demotivating cause of poor employee performance. The attitude is counter-productive from the start. But why argue if you are a mind-made-up proponent of the opposite view. Most pioneers may be "employees". But when it comes to civilian rights, it gets no one anywhere to reduce them to that. It solves nothing to start off with the same stupid "adversarial mentality" we find in management labor relations in this country.

Let them earn it, you say. I say so too. But then it is fair to preagree on what performance earns what rewards. If circumstances and situations change and show that the "schedule of progress" is unreal-istic, too fast, too slow, too jerky, whatever, there should be a proper means of amending it.

In the past, in all situations of political process I know of, especially throughout the whole global decolonization period, every step had to be negotiated - or fought. There has always been a succession of regimes, of charters, of constitutions.

I suggest that this is neither necessary nor advisable. One charter could do it all if it is fully and clearly spelled out that these conditions being met, this would be the degree of home rule. Make more progress toward pre-agreed goals, get greater degrees of self government including the right to establish a bill of rights, a division of powers, and other features we normally relegate to a constitution.

Should the outpost never become more than that, no problem - it's all spelled out. Everyone knows the rules. If a settlement comes into its own and thrives and spreads beyond expectation, the charter provisions are in place to guide it. Revolu-tions of independence can be avoided. They cause a lot of damage that can take decades to undo.

The foregoing is just a generalized expression of the approach I think we need to take. There are a lot of unanswered questions. We can start identifying the questions, not trying to answer them right away. And I hope that many of you readers will get involved and help identify more questions, more problems, more possible approaches. Who knows maybe we can produce something.

We are not yet talking constitutions, nor yet discus-sing a Bill of Rights, nor the division of powers nor how the legislature be constituted - we can eventually propose and advise, leaving it to the pioneers to choose. What we are doing here is brain-storming presettlement charters that will govern the pioneers' political progress towards maturity. <PK>

$elf-$ufficiency Tests & Goals

by Peter Kokh

We've already hinted at some not directly economic things that might be considered as bench marks of pioneer and frontier achievement "meriting increased home rule":

- increases in population, e.g.: 100, 300, 1000, 5000, 25000, 100,000, 250,000, one million
- educational capacity: K12, technical college, full university (list of critical departments), degree of involvement of the university in creation of new enterprise and in increased industrial diversifi-cation, involvement in arts and craft media devel-opment, fractional gravity-sensitive performing arts, etc.
- medical capacity:
    - capacity to treat most trauma, common diseases, pediatrics, maternity ward, etc.
    - advanced capacity: neurosurgery, oncology, etc. (advances counted in reduction of the percentage of cases that must either be sent to hospitals on Earth or left to die as comfortably as possible.)
    - medical advances in the area of lunar-peculiar medical problems
- progression from an all worker society towards the normal mix of working adults, children, and seniors given productive roles suited to their slowly diminishing capacities
- Progression from a one settlement operation to an actively intertrading association of frontier communities with consequent growth both in domestic and export economies
- increases in the ratio of native Earthborn indivi-duals electing to stay in comparison to those still rotating back to Earth
- increases in the proportion of native born Lunans
- ongoing assessment of the comparative health of native born Lunans over several generations
- Diversity of the gene pool (another article)

Balance of Trade QUE$TION$

by Peter Kokh

The following additional items are vital because they affect the economic viability equation:

- stockpiles of critical imported reserves (volatiles not yet produced in enough quantity locally, emergency food rations, parts for essential equipment, backup power units, etc. etc.) e.g.: 6 months reserves, 12 months, two years
- increases in percentage of architectural and building products and units manufactured on the Moon versus imported from Earth (increases in the degree by which population expansion can be wholly supported locally)
- increases in the percentage of food and other agricultural products grown locally both in terms of total tonnage and in diversity (progress towards a locally supported diversified foods menu)
- increases in percentage of total mass of products manufactured on the Moon in comparison to the total mass of products that must be imported from Earth (reductions in import dependency)
- increases in the number, relative worth, and deferred import value of new lunar sourced "substitution products" to replace items that had been imported from Earth because equivalent products could not be manufactured from commonly available lunar materials
- increasing levels of industrial and commercial diversification (economic insurance against the vulnerabilities of one export product economies)
- increases in the percentage of exports sold to other space markets (including LEO and GEO) in relation to those sold directly to Earth.
- Increases in the diversification of products sold to other space markets

- Increases in the percentage of imports from other space markets in comparison to those coming from Earth (these last three considerations will indicate the degree of integration of the Lunar economy into an emerging wider solar system economy extra terrestrial sector.)
- Growth of a local machine tool industry
- Growth of a local electronics industry
- Growing percentage of surface vehicles, for out-vac and in-habitat use with majority (by mass) content locally manufactured
- growth of spacecraft servicing and reoutfitting capacity

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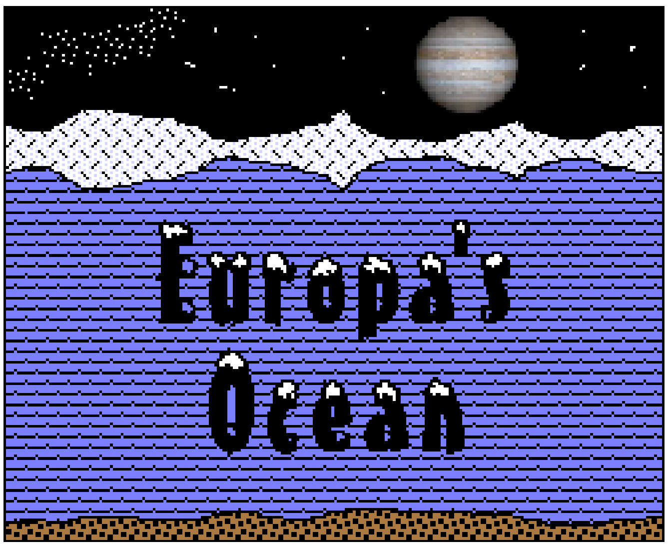


The evidence that Europa has a global ocean under its protective ice crust - an ocean that may hold more water than Earth's - continues to mount

MMM Special Report

To some of us, the first indications in the mid seventies that this relatively billiard ball smooth ice-encrusted world somewhat smaller than the Moon had an ocean of water beneath its crust kept liquid by the mighty tidal forces exerted upon it by massive Jupiter, was "so elegantly correct" a conclusion that we accepted it as fact from that moment on. After all, ice is water, and water is two parts hydrogen (the most abundant element in the universe) plus one part oxygen (the 3rd most abundant element). To envision that such oceans could exist is hardly a symptom of wishful romanticism.

Yet there have been many who have "reserved judgement". Some, I am convinced are simply haunted by the fear that Europa's ocean will turn out to be this generation's equivalent of the "Martian Canals". I'm sure that they all see this caution to be proper conservative scientific posture. But it would seem to us that there is a good deal of temperamental bias plus a healthy dose of terrestrial chauvinism at work in such skepticism. For one, we want to instinctively protect the age-old tenet that Earth is special.

Well it is. Even though, by my own back of the envelope guestimate, there may be a thousand times as many "Europids" throughout the universe as there are planets like Earth, Earth still remains special. Our ocean is "exposed to the open sky", protected by a blanket of air, rather than by a "firmament" of ice. That introduces not only an exposed liquid surface that can be sailed and navigated and fished, but also oxygenates the entire ocean. An unexposed cocooned ocean will be a very different ocean, even if in cubic miles it is amazingly bigger than ours.

All about Tides

The formula for the relative strength of tidal forces is Mass times the inverse cube of the distance [M/d^3]. Here M = 25,844 (how much more massive Jupiter is than the Moon) and d is 1.745 (Europa's mean distance from Jupiter is that much greater than the mean Earth-Moon distance - this greater distance will moderate the tidal force).

Solving the formula, we get a tidal force 4,861 times that exerted by the Moon on Earth's oceans. So even though Europa is further out from Jupiter, Jupiter's mass is so enormous that we still have a tidal force 5 thousand times greater than we experience on Earth.

These points, illustrations, comparisons:

- Io is about a third closer to Jupiter than Europa: d [in terms of the Earth-Moon distance] being 1.097. Io experiences a globe-wracking tidal force two and a half times stronger than does Europa. This tidal heating has long since driven off any water Europa may have once had, and powers Io's amazing volcanic activity.
- Earth, 81.3 times as massive as the Moon, exerts that much stronger a tidal force on the Moon. The Moon has no ocean to absorb this energy. Instead the effect works to slowly but surely push the Moon further and further away from the Earth, while Earth's rotation slows down and its day gets longer from the friction of the ocean tides.
- The Sun is 27 million times more massive than the Moon but nearly 400 times [389] further away from Earth. By the inverse cube (yes, not the inverse square) rule, that diminishes the Sun's influence by a factor of 59 million. The result: the tidal forces exerted on Earth's oceans by the tiny Moon is more than twice [2.2] as strong as those exerted by the massive but distant Sun
- Lunar tides in Earth's oceans occur on a twice daily basis, the force being strongest when the Moon is at the noon position in the sky, and peak again when it is in the midnight position. The actual tides lag behind by a few hours.
- On Europa, which keeps the same face turned toward Jupiter, the fluctuation in tidal force occurs as it ventures closer to Jupiter in its orbit, then further out in its three and a half day long orbit.
- It is this difference between maximum and minimum force coming from relative orientation, relative distance, or both, that causes the actual disruptive force.

Some scientists have grudgingly admitted that Europa may "once have had" an ocean, but have been loathe to admit it still has one. But what is special about our epoch, that while we are around to witness it, the ocean should have frozen, as if overnight?

Yet, until we can detect the thickness of the ice and "find" the lower ice surface-ocean interface and *map* it, some will be happier to pretend that we don't "know". No one wants to be caught believing in our generation's equivalent of "Martian canals." Yet mainstream thought is that Europa is not alone in this solar system. Callisto, Ganymede, and far distant Charon may have subcrustal oceans as well. In Callisto's case, where the ice crust is so thick that no one dreams of penetrating it, the evidence from its surprising magnetic field almost shouts the answer. Electric currents in a deep salty ocean are the only explanation so far that fits the magnetic data profile.

Back at Europa, the alternative explanation championed by the doubters is "warm, convective ice". We should not have to wait until Europa Orbiter arrives on the scene with its icecrust-penetrating radar to tell which is right. The two theories will be told apart by analyzing surface features and their causes. Different conditions can produce overlapping sets of symptoms but with telltale distinctions.

September 12th, JPL scientists announced an ingenious new test to find telltale evidence the in ice crystal structure of Europa's surface. [See NASA Space Science News: http://science.nasa.gov/newhome/headlines/ast09sep99_1.htm]

Meanwhile, another team has come up with a graphic computer demonstration that offers the first convincing explanation of a curious surface feature seen in many places on Europa, one which has had scientists perplexed for over two decades - rows of scalloped "cycloid cracks". And the envelope, please!

Europa:s Cycloid Cracks or "Flexi"

http://pirlwww.lpl.arizona.edu/~hoppa/science.html
http://www.spaceviews.com/1999/09/16c.html

Cracks Best Evidence Yet for Europan Ocean

[Text below from Spaceviews story]

In a paper published in the September 17 issue of the journal Science, four Univ. of Arizona researchers concluded that a set of curved cracks called "flexi" on Europa are caused by tidal stresses from a subsurface ocean.

Flexi are cycloidal cracks that appear as a series of arcs, joined together at each end to form a long, wavy crack across the surface. The cracks, unique to Europa, were first noticed in Voyager images in 1979, and have been studied in more detail more recently by Galileo, but have defied explanation until now.

"What causes the cycloid to form is that Europa is in a slightly eccentric orbit because of Io and Ganymede," two other large moons of Jupiter that orbit closer and farther from the planet than Europa, explained lead author Gregory V. Hoppa.

The varying distance of Europa from Jupiter causes tides in the hypothetical subsurface ocean to rise and fall as Europa is closer and father, respectively, from the planet. These tides can rise and fall as much as 30 meters (110 ft), compared to the 1-2 meters (3.3-6.6 feet) for most terrestrial tides. "This causes Europa's ice shell to flex," said Hoppa.

When the tidal stress exceeds the tensile strength of the ice, a crack forms. That crack propagates along a curved path on the surface until the stress drops below the strength of the ice, at which point the crack stops.

Each arc in the flexi is 75 to 200 km long [45 to 125 miles long], and forms over the course of 3.5 days, the orbital period of the planet. "You could probably walk along with the advancing tip of a crack as it was forming," Hoppa said. "And while there's not enough air to carry sound, you would definitely feel vibrations as it formed."

The U. of Arizona scientists believe this is the most convincing evidence yet [for a subsurface ocean] since no other mechanism can explain the formation of the flexi.

"What amazes me about this is just how long these features have been a mystery," Hoppa said. "We've been staring at pictures of them for 20 years since Voyager. We didn't know what made them. And it seems what they've been telling us all along is that an ocean was there when these things formed."

[MMM: for readers who are online, the authors have created an animated image of cycloid crack forming:

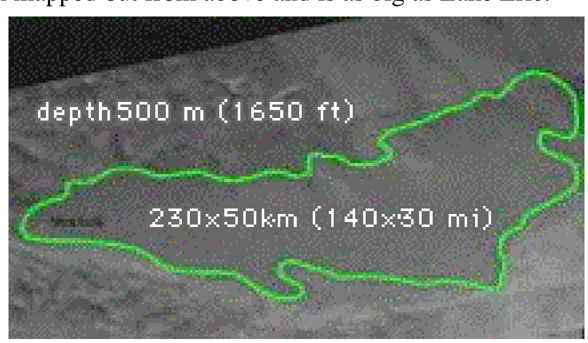
http://pirlwww.lpl.arizona.edu/~hoppa/science/cycloid_69s_240w.gif]

Plans to explore Lake Vostok, Antarctica

A fortuitous analog of Europa's ocean here on Earth

As reported earlier in MMM, Soviet scientists drilling through the antarctic ice cap near their Vostok station in the "inaccessible" interior of the ice covered continent, stopped the operation when readings indicated water, not ice, 120 meters (395 feet) ahead. That was in 1974, by sheer coincidence about the time when Guy Consolmagno first proposed that Europa had an ocean under all that ice.

Further soundings have shown that this subglacial water pond in Antarctica is substantial. Lake "Vostok" has been mapped out from above and is as big as Lake Erie.



Above: In 1993, altimetric and radar data were used to trace this outline of Lake Vostok, located about 1000 miles from the South Pole. Image © the Canadian Space Agency.

Buried under 3,700 meters of ice [12,000 feet], it is as large as Lake Ontario and as deep as Lake Superior. The Lake has been there at least a half million years (some say 35-40 million), and may host a microorganism ecosystem quaranteened from the surface biosphere since. The lowest temperature ever recorded, -89.2°C (-128.5°F), was registered nearby.

Scientists did not want to resume drilling until they were sure that the operation would not contaminate the Lake, making it impossible to do a definitive study of its expected ecosystem.

Yet those who saw here a fortuitously close analog to the situation we find on Europa, have been eager to see the drilling resumed. Some hold out hope that Europa's ocean will not be a sterile one, but harbor an ecosystem of some unimaginable kind as well. Others think that the odds are that either Europa's ocean was never seeded with life, or that the nutrient needed to sustain life and evolution are insufficient. The stakes are high. Europa could be more friendly to life than Mars. We have to find out.

Cautiously, two scientists examined the ice cores from just above the Lake. The extremely deep ice samples from approximately 100 meters above the surface of the lake were obtained by an international team of US, Russian, and French scientists. Using an Environmental Scanning Electron Microscope, Richard Hoover of NASA's Marshall Space Sciences Lab and Dr. S.S. Abyzov of the Russian Academy of Sciences were looking for evidence of microbiotic life.

> "We've found some really bizarre things - things that we've never seen before," said Hoover. "There are all sorts of microorganisms in the ice. Some are readily recognizable as cyanobacteria, bacteria, fungi, spores, pollen grains, and diatoms, but some are not recognizable as anything we've ever seen before."

Above: One of the more exotic forms Hoover and Abyzov found in the deep ice above Lake Vostok. Many of these microbes will undoubtedly fall into known categories when identifications are made.

These findings only whet the appetites for those who want to explore the Lake itself. Geologists want to explore its morphology and the topography of the bottom as well as of the containing underside of the ice sheet above, test the ages of different features from which to deduct a history of the Lake's formation, and probe the possible rocky-muddy bottom, look at its mineralogy, measure the heat flow through the Lake bed that is responsible for maintaining the Lake's liquidity, and test the degree of salinity and oxidation of the water itself.

Biologists, especially the emerging sector now examining life in extreme environments, want to look for life in this 500,000 to 40 million year old time capsule. For those interested in what we may find on Europa, all this is very exciting, heady stuff.

Similarities between Lake Vostok and Europa

- a kilometers-thick ice-sheet covering and quarantining a major body of liquid water
- an environment where life may have developed in isolation along unique evolutionary paths
- subsurface bodies of water accessible to remote observation via radio sounding techniques and *in situ* observations by means of melting probes that may call for technologies beyond or at least at the cutting edge of today's know how
- An imperative to examine and explore with techniques that do not contaminate the environment we are exploring, spoiling the results, as well as doing harm to any ecosystems present

It is not surprising that those interested in exploring Lake Vostok, and those interested in what may lie beneath Europa's ice crust are now actively working together brainstorming techniques, procedures, and strategies. Together they are looking at:

- how best and most efficiently to get through the ice barrier with a "cryobot"
- how to put a "hydrobot" probe in the lake/ocean below without contaminating it
- how to maintain telemetry contact with the probe as it explores its remote location
- how to design a hydrobot probe that will do gather all the data we need it to gather

Not surprisingly the Europa and Lake Vostok probes, both cryobot and hydrobot sections will be very similar, as will be the procedures to get them through the ice and to stay in contact. But Europa investigators, who must accomplish their mission by remote from Earth will have a more challenging task than the Lake Vostok team at their forward post atop the ice sheet 1,500 km (900 mi) from the nearest coast. This makes this opportunity to explore Lake Vostok first most helpful to the Europa scientists.

JPL, U. Nebraska, and Woods Hole Oceanographic Inst. Scientists and engineers are trying to identify technologies needed both at Lake Vostok and Europa. Lake Vostok will challenge current technology, but with NASA technology a safe entry may be possible.

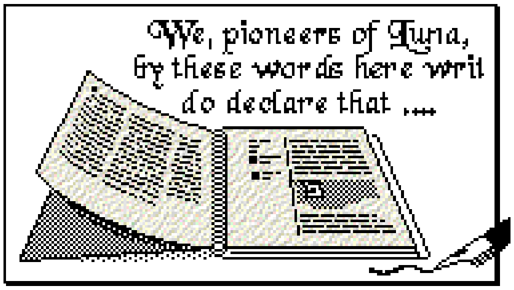
http://news.bbc.co.uk/hi/english/sci/tech/newsid_458000/458586.stm

<MMM>

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

MMM #130 - NOV 1999



Personal Rights & Freedoms on the Space Frontier

The American "Bill of Rights" was not a part of the United States Constitution proper, but added on (Amendments 1-10) as an afterthought. Yet we cannot conceive of what our "Way of Life" would be like without it. Should we just duplicate it, item by item in Space Frontier constitutions? The Space Frontier poses a whole new set of challenges never before faced by human communities. Do we need special safeguards to protect basic freedoms in such an environment? See below.

In Focus The Lunar Rock Pile: Behind "Door #1", "Door #2", "Door #3", etc.

The "in" Team of Aldrin, Goldin, and Zubrin would have us all chant along with their refrain "Been there, done that" to the Moon Putdown Blues. It is easy to see why. From a first blush quick superficial look, that's all the attention most people give anything, the Moon is quite obviously a monotonously gray rock strewn desert of unspeakable barrenness. The Moon is obviously a Rock Pile. We found that out. Let's move on.

But guess what? Like the backdrop of the classic TV hit show "Let's Make a Deal!", the Moon's façade is only an apparent global dead end. It has unseen "doors" behind which lie a world of unsuspected potential.

Behind Door #1: The "location" and "outline" of the first "door" to the hidden potential of the Moon was hinted at in the Apollo moondust and moon rock samplings and their analysis. An abundance of oxygen, silicon, and calcium, plus an abundance of the three major "engineering metals": iron, aluminum, magnesium, titanium. We've but to look through the door's peephole. The key to open this door lies in homework we can do on Earth. We need to know how to isolate or "produce" these elements out of the mineral complexes in which they are combined, more inconveniently than we'd like. Except for iron, a considerable amount of which is available unoxidized, in pure metal fines, in the "pre-mined" upper regolith, a "blanket of dust" pre-pulverized by eons of micrometeorite bombardment. We need only a magnet to harvest this resource. But otherwise, largely because the Moon did not undergo tectonic processing of its crust in the presence of water (hydrotectonic processing), it has no ore veins of concentrated metals in simple mineral combinations. The Moon's mineral wealth is not to be gotten so easily. But it is there.

We need to do processing experiments, using simulant soils superior to those we have toyed with to date. They must resemble moondust not just in the percentages of the elements represented, but in the chemical mineral combinations to be found on the Moon, as well. We have no, or little, experience extracting elements from such minerals. Yes, we have done some work on figuring out how to extract oxygen. But to paraphrase a well known proverb, "settlers do not live by oxygen alone."

Nor is it enough to do "lab" experiments. Techniques suitable on so small a scale are often unsuitable for scaling up to "production-batches". "Chemical Engineers" need to be involved -- the guys who can design factory-scale chemical processing.

Nor are the raw engineering metals enough. We need to develop ways to extract and isolate many elements present in lesser abundances as alloy ingredients, color pigments, as ingredients for glass, glass composites, ceramics, cement and manufacturing stuffs and building products in general. The dance card of the chemical engineers is quite full.

How can we do this homework without federal funds? We brainstorm profitable terrestrial applications of the techniques and processes we are developing for the lunar frontier. That way we make money now and at the same time put "on the shelf" the technologies we need once we get there, paid for out of the profits of terrestrial applications, not taxes. This is the "spin-up" route.

Many still look to the rocket scientists to deliver the Promised Land. But as much as we need them to figure out how to realize "cheap access to space", it is the chemical engineers who will be able to tell us how to access space resources. (And without the agricultural and biosphere engineers and the human factors engineers, there won't be any "we" out there to do any thing with these resources.

If you in search of a career that will put you at the forefront of opening the space frontier, one of the options just listed may be for you. Space is a place. Transportation just gets us there. After we arrive, we need to have opened these "doors" if we aren't just going to sit there "stranded".

Behind Door #2: The location of this "door" lay in two clues: the Moon's axis is nearly perpendicular to the plane of the Earth-Moon system's orbit around the Sun. So the Moon has no seasons. As the Moon is not a perfectly smooth sphere, there must be places near both poles, in craters at least (crevasses are not a lunar feature), in which "the Sun never shines." These "permashade areas" are stable "cold traps", very frigid places where volatile elements (relatively high boiling points, with the vapor or gas easily dispersed by the incessant solar wind) might have accumulated over millions and billions of years.

NASA planned a Moon Observer, equipped to answer the question of whether or not any cometary volatiles, dispersed in nighttime impacts with the Moon, might have reached the polar cold traps before the Sun arose over the horizon to disperse them. But this probe was a "phantom mission". The craft was to be the "backup Mars Observer". Congress, as superficial as most everyone else, convinced that there was nothing useful to learn from further Moon missions, and in an effort to rein in Mars Observer program costs, canceled the backup craft. Almost end of story!

Scientists and space activists knew the "ice question" was important, deserving an answer. To our collective credit, Lunar Prospector was born and designed outside NASA. LP was available as a Discovery Mission project when the opportunity finally arose. The rest is history. Lunar Prospector's instruments found several times as much hydrogen at the poles in permashade polar cold traps as exists elsewhere (per unit area). Unlike the hydrogen to be found globally, embedded in surface soils by Solar Wind buffeting over billions of years, the polar hydrogen signal data are best explained as coming from water ice, rather than excess concentrations of Solar Wind protons. The Moon, it seems, "behind Door #2", has major reserves of water ice at both poles.

As an elegant afterthought, as the "Little probe that Could" wound down its extended mission at low altitude, it was aimed "blind" towards a crash landing into a polar crater expected to contain layers of water ice. The hope was that the impact would throw clouds of dust and telltale water vapor, high up enough above the rim of the Moon to be detected by Earth-based instruments as well as by Hubble.

It didn't happen. But to look at the media headlines, "Lunar Prospector fails to find water", some of these headlines echoed in pro-space publications (for shame!), you would think that all the data LP had gathered in the past eighteen months was somehow now suspect!

Balderdash. Even if the selected crater does have a bottom-filling ice layer, several things could have prevented a splashout:

- the craft, impacting at low angle, did not penetrate all the way through a surface layer of dust expected to cover the ice layer.
- the craft may have haplessly impacted the side of a large boulder or rock outcrop that was ice-free (seem's reasonable enough!)
- the water vapor may have reacted with the soil as it accumulated, producing cement cakes rather than ice. We need to have a ground truth probe to find out. But perhaps the Powers That Be are happy not to have a "positive finding" lest they be derailed from their preoccupation with Mars. (We need to explore and settle *both* worlds!)

Those who want to access what lies "Behind Door # 2" need to put together a segue discovery mission, this time to land at one of the poles and do a ground truth search and a quantitative and qualitative assay of whatever reserves it finds. Lunar Polar Lander, like the "lunar polar probe" later renamed Lunar Prospector, will almost certainly be *up to us*. The most we can expect is that NASA will pay the costs as a Discovery Mission opportunity if we can keep those costs down to a bare minimum, and if the craft is as capably instrumented as it needs to be to get the job done.

Water is essential for life support, agriculture and the biosphere in general as well as closed-loop industrial uses. It is NOT essential for rocket fuel. Liquid hydrogen IS invaluable *for getting us out of the deep throat of Earth's gravity well*. We can do well enough with less potent substitutes once we are in orbit and beyond. To burn up an unreplaceable resource to get our rockets off - all in a one-time non-reccylable impatient exercise makes no sense. If this polar hydrogen resource *is* in the form of cement hydrates instead of free water ice, it will be harder to access. That may prove a blessing as it will work to discourage the pillagers more than the settlements.

Behind Door #3: Lunar Prospector mapped the lunar globe by tracking a number of elements. One of these was the radioactive element thorium. There are apparently appreciable reserves of this element in various areas of the Moon. Thorium is transmuted into fissionable Uranium 233 in a fast breeder reactor. Thus the Moon apparently has the wherewithal for a major nuclear fuels industry.

Thorium and Uranium 233 are nuclear fission fuels. They produce energy by the splitting of heavy atoms. The atomic bomb and all current nuclear plants operate on the fission principle. But the hydrogen bomb and nuclear plants built to operate on the same principle, produce energy by combining lightweight atoms (hydrogen, deuterium, tritium, helium-3). Now it turns out that the same solar wind which has put a considerable amount of hydrogen protons into the lunar topsoil or regolith, has also endowed that layer with a wealth of Helium-3, the ideal fuel for fusion reactors, if we can overcome the engineering hurdles in making such plants a reality. Helium-3 could be the long term cure for Earth's stubborn energy and environmental problems.

As to the fissionable Th/U233 resource, this too may be an invaluable export. Fringe environmentalists could conceivably succeed in banning the transport of all nuclear fuels through Earth's atmosphere. While chemical rockets can support Mars exploratory expeditions of trained and dedicated crews, that real settlement, migration to Mars is most unlikely unless we have fleets of nuclear ships able to make the trip in much less time and over extended launch windows. Two plus two = .. . You guessed it! In that not improbable scenario, Lunar Thorium could fuel the opening of the Mars Frontier.

Behind Door #4: It would seem that the entire surface of the Moon is exposed to the wind and waves of cosmic weather. Micrometeorites rain down incessantly *everywhere*. The intense raw solar ultraviolet washes *everything*. There is no shelter *anywhere* from the fury of Solar Flares and cosmic rays. The Moon's surface is an unending, unbroken desolation that is as deadly as it is magnificent.

The first hint that this was not the whole story came with the Apollo 15 landing mission alongside Hadley Rille, a winding "sinuous" valley. Upon examination, the valley did not seem to be "carved out" by either water or lava. Instead it is the relic of a subsurface lavatube, what is left of it after the roof collapsed on top of its floor, creating the trench above. From orbit, we've looked at similar "sinuous rilles" elsewhere on the Moon. They are a feature to be found only in the congealed lava flow "seas" called maria, usually near the "coasts" where the highlands begin or end. And lava sheets, formed by runny lava (like the kind that forms shield volcanoes) are just the sort of environment in which lavatubes form. Indeed, lavatubes are the principal means by which these sheets advance over the terrain they end up burying.

It would seem that to protect ourselves, we must build outposts on this storm-washed surface, then pile up a healthy layer of moondust on top, to serve as a solid protective blanket in the same way as Earth's atmosphere provides a gaseous blanket to offer us the same protections.

Have all lunar lavatubes collapsed? Do they only exist as relics? as natural ruins? Apparently not. Some such rille valleys are discontinuous. They consist of a number of sections separated by "interruptions" of apparently normal looking flat surface continuous with the surrounding host terrain. These natural bridges can only be interpreted as surfaces hiding intact lavatube sections. And where we have partially intact lavatubes it is reasonable to expect we will find some that are both wholly intact and not flood-filled by subsequent flows. Other evidence comes from rows of "collapse pits", rimless craters that are a sure sign of caverns below.

The maria may be ridden with these tubes, and not just in the surface layer. As the mare [MAH ray] sheets built up layer by layer, tubes would have formed in each, some to be later flooded, some not. And wherever the surface-ceiling cover exceeded 40 meters or so, cave ins and overall collapses will have been unlikely except in case of a direct hit by a sizable asteroid tidbit.

These lavatubes, of immensely larger scale than those we find on Earth, thanks to appreciably lower lunar gravity, and, immensely more ancient (billions rather than thousands of years old), provide hidden but real anchorage, safe harbors not only from the cosmic elements and solar weather, but also from the extremes of surface dayspan heat and nightspan cold -- *and* from the mischievous moondust that is otherwise everywhere.

We need to map these subsurface features, something that has yet to be attempted. Tom Billings of the Oregon L5 Society has brainstormed a two-part sleeve/core "radar flashbulb" probe design. Aimed at promising sites, the probe would be aimed to impact the surface, forcing the outer sleeve to telescope over the inner core and thus generate an electro-magnetic signal at just the right frequency to illuminate any "voids" within say 8 kilometers of the impact area. The signals reflecting off the hidden voids will be readable by either a wide-array of radar telescopes on Earth, or a dedicated space radar array in near-Moon space.

Designing the probe and proving the concept is one thing. Picking the right targets is another. The plan is to use special computer software to examine the voluminous Clementine high sun angle photographic data, looking for telltale shadows of "skylight" and "terminal" entrances to tubes. This search will take both time (possibly 18 months of run time) and money. An Application to the FINDS Foundation in July, '99 has generated no response as yet. Your donation, large or small, to the Oregon L5 Society Lunar Lavatube Locator project will help us open "Door # 4". Lunar Prospector took ten years to become real. The longer we delay the LLL project, the longer we delay a real opening of the Lunar Frontier. Your donations can help save us all time.

A successful mission or series of missions, possibly flown as Discovery opportunities, will forever change how people look at the Moon. It will be suddenly more than a boring rock pile. It will become, in the public awareness, a real world with real safe harbors and protected hidden valleys.

There are other hidden doorways to the Moon of "unsuspected world-potential", and it has been MMM's guiding mission to uncover the possibilities one by one.

Next time you hear someone say "The Moon? Been there, done that!" you will know that you at least are able now to see behind the rock pile face to the "real Moon inside" -- a rock that can become a world, if we only open all the right doors.

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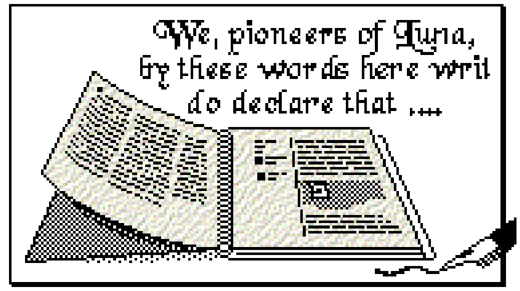

A Bill of Rights for Space Frontier Communities:

by Peter Kokh

What can we take for granted?

No part of the U.S. Constitution seems more quintessential to our way of life than the "Bill of Rights". Yet actually, it was an afterthought. After the rest of the language of the Constitution had been drawn up and met with the framers consensus, all the questions about the structure of the government and the division of powers seemed to have been answered. Then it was noticed that the document did not address the relationship of citizens to one another or to the government. The absence of a statement on these rights was handled by a set of ten ammend-ments. The Constitution with these first ten ammend-ments was then voted on and approved as a package.

Lesson learned, framers of any space frontier consti-tution need to address individual rights in the same package as they attend to organizational matters and the division of jurisdictions and the schedule for achievement-triggered levels of autonomy. But it may not be so simple a matter of just tacking on our own Bill of Rights.

First of all, these present ten amendments have led to two centuries of legal squabbles about how literally or freely they must be interpreted. There will be many calls for rewriting them in language that is clearer about the intent in which they are to be each applied. We will bring up some of the points most in contention.

Secondly, some of the succeeding ammendments further clarified individual rights. And Supreme Court interpre-tations have generally served to strengthen individual rights against those who were happier with those rights being unestablished.

More to the point, on the Space Frontier we will be dealing with the rights of people in a wholly new, unprece-dented, and never imagined set of circumstances which arguably changes everything. For the first time we will be talking about individuals who do not live in a pre-given world-wide life-sustaining biosphere. We will be talking about the rights of individuals living in artificially established and maintained mini-biospheres that are local in character, and outside of which, whether on hostile planetary surfaces, or in the void of space itself, life cannot be sustained. Such situations have never previously existed. Thus they have never been addressed. It is the writer's contention, that the "Space Frontier Condition" changes everything, to one extent or the other.

No government on Earth need guarantee, either in its constitution or in subsequent legislation, the right to air, water, sufficient heat so as not to freeze to death, and even food. Except in the most extreme weather, most people can survive out in the open for quite some time, even indefinitely. On the outside you will still find air to breath, water to drink and, if you know how to forage and/or hunt, food. The resourceful person can also find warmth. Put outside the airlock, without the provision of countermeasures, no one can long survive on the space frontier. We're all in it together, and our common humanity decrees we all have rights that it never occurred to anyone to define and guarantee.

"Lifeline Services"

On the space frontier, the distinction between "indoors" and "outdoors" lists the options neither accurately nor completely. There is a great gray area which from one point of view is "outside" - at least outside individual private of public structures, and which from another point of view is "inside" - inside the biosphere containment hull, shell, dome, or whatever preserves the common life-sustaining barrier against the exterior vacuum or unbreathably thin and/or unbreathably composed alien atmosphere. Both inside and outside become ambiguous.

Nearly thirteen years ago, in MMM # 5, MAY '87, we introduced the term "middoors" for common spaces within the Biosphere containment shell as opposed to "indoor" spaces within private homes and private and wall-defined buildings, etc. Later, we introduced the word "out-vac" (modeled, of course, after the Australian word "outback") for the airless environment outside the biosphere airlocks. [On Mars we might substitute the word "out-gasp" **:-)**]

Although I can think of a lot of people who'd be excluded by their "devil-take-the-hindmost-*because-I-know-how-to-get-mine*" mentality, it would seem to me that most reasonable people would come to agree that we must address three things:

- an individual's right to remain within a biosphere, once he/she is in, with the burden of finding alternative residence possibly resting upon the biosphere's authorities
- an individual's right to be homeless within a biosphere's common middoor spaces, with the burden of finding alternative residence possibly resting on the biosphere's authorities
- an individual's right to basic life-sustaining utilities within a private residence whether or not he/she can afford to pay for them

Now we can discuss all we want where rights end and responsibilities begin. But we must never forget that we are not talking about Earth. We all strongly prefer to have only responsible, industrious, contributing citizens on the space frontier - no dead-weight, thank you. But we've all heard, and hopefully had the occasion to say with sincerity the humbling phrase "There, but for the Grace of God, go I!" While not all of us have ever been "down and out", we all know that someday we could be. On the space frontier that is a condition enormously more threatening. Unless we establish a regime of rights and responsi-bilities to address unfortunate circumstances.

Now a constitution might keep its language general and simply state that any individual has the right to remain within a settlement's biosphere pending the location of a non-life-threatening option; that any individual has status within the settlement's middoor commons without restriction to those having established indoor residences; that any individual has the right to minimal hook-up biospheric utility service to his/her place of residence. The P's and Q's and the crossing of the T's and dotting of the i's can be left to subsequent legislation. But here is a list of "life-sustaining' services and rights that I will throw out to get the discussion going:

- no cost "indoor" temperature control within the range set for middoor common spaces, e.g., free heating up to 50 °F or 10 °C and free cooling down to 85 °F or 30 °C (arguable but reasonable)
- basic "safety" level lighting
- fresh water in (a "reasonable" ration), waste water removal
- fresh air in ("reasonable" rate of flow ration), stale air out
- access to food at both no and low cost
    - Right to grow food in community gardens
    - Right to "staples" and a share of "seconds"
- Right to minimum outbound communications
    - free calls to public officials, health authorities, emergency hot lines
    - business subsidized free calls to advertisers
    - caller-paid incoming calls
- Right to volume-rationed free storage for personal effects
- Right to rationed-access public bathing/shower facilities/laundry
- Right for traditional or non-traditional family groups to be relocated together
- Limited right to education, training, retraining
- Limited right to handicap challenge training
- Limited right to Entrepreneurial technical / business assistance
- Right to Occupational services, retraining
- Right to basic Educational services
- Right to Universal service training and placement opportunities

This is admittedly a long list. It is not aimed at giving away the farm, of giving people something for nothing. Extension of these rights would be a calculated risk to ensure that everyone remains productive or has every opportunity of recovering from misfortune to become productive and useful again. It is neither in the common interest to allow the creation of a homeless class of outcastes or untouchables, nor to settle such problems "cheaply" by putting the unfortunate "outside the airlock."

These provisions are aimed at minimizing as far as possible the number of settlement "residents at large" with no home other than the middoor streets and parks and other common spaces. Finding ways to keep people in homes and with access to the means of getting back on their feet is in everyone's interest.

Other Issues - comments on basic freedoms

- Refining the separation of Church and State: We should be careful to assure the right of and from both religion and culture. This right should not be interpreted so as to deny equal educational access and tax-paid common tools to those who do not wish to subscribe to the common culture.
- Mindful of the need of space settlements to control expensive imports, especially in areas where there are substitution alternatives, governments may be inclined to take advantage of their prerogative to establish import protocols to restrict the right of individuals to own non-electronic forms of books, papers, and other knowledge packages. With such a stricture might come the temptation to "censor" or otherwise restrict incoming electronic memories. Perhaps this would not be a problem. But should a constitution specifically guarantee "the right to own books" etc. and other repositories of information, art, imagination, and expression? It couldn't hurt.
- One of the unestablished rights over which there is now much debate, is the so-called "right to die", with assistance where necessary. Will some practical consensus be reached in coming years?
- Should a person on the space frontier be able to exercise "the right of exile" or of repatriation in preference to incarceration? These options of "removal" from the free population might be cheaper.
- Should "the right of travel" be guaranteed?
- The "right to work past retirement age?"

There are other debates about rights that I have not mentioned. Call, write, or email me about glaring "omissions" Contact information is given below the masthead on page 1.

Nor have we addressed the question of constitutional "Duties & Responsibilities." Perhaps we will venture into this danger fraught area in Next Month's MMM!

Discussion is open. <MMM>

Settlement Sociology

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Consider, if you will, the old Twilight Zone episode where an astronaut is locked in a simulated space capsule for a few days to see if he can stand the loneliness. Of course, the answer is, no. In reality prisoner-of-war camp experiences, natural disaster experiences, and the like -- even the experiences of real astronauts -- all attest to the emotional hardiness of human individuals.

Having acknowledged that, it is, nonetheless, important to face up to the fact that serious and ever increasing social consequences do result when humans are put in situations where their spiritual, emotional, intellectual, and/or mental health needs are not being adequately met. Failure to provide for these needs will sooner or later lead to more illness, a rise in accidents, increases in various forms of violence and vandalism, reduced productivity, increasing costs of maintaining the society and its infrastructure, and many other problems. In the setting of an early space settlement, even a small increase in negative social behavior could greatly reduce the settlement's chances for success and continued viability.

Once a true ***settlement*** in space is established it won't be long until those populating it will not only consist of people of both genders, but also of all ages, intellectual levels, abilities, interests, a wide distribution of states of physical and mental health, each individual unique in genetic disposition as well as experiential background. The more individuals in a community, the wider the range of needs which must be addressed if the settlement is to maintain its viability. Formal social systems will be necessary to recognize as many of the needs as possible and take deliberate steps to provide for them. Think about it. Besides obvious physical and mental handicaps, there are bound to be feelings of unhappiness, personal adversity and frustration, the need for personal fulfillment, even the need to play. These can't be left to fester ... not in a community as interdependent and as susceptible to catastrophe as a space settlement would be.

There are really two sides to this issue. For those who start out with reasonable mental health and are reasonably well adjusted socially, there are the things they need to remain in that positive state. For those who are already more or less mentally unhealthy and/or are not functioning well socially there are the things and conditions they need to change for the better (and to a sufficient degree) that they become members of the healthy, reasonably well-adjusted group. Or else they must, in some other way, be made harmless to the society.

A High Risk Game

It is important to remember that we are discussing these things in the context of early space settlements. In such a setting the very existence of the community will almost certainly be balanced on a razor thin edge. A single terrorist act, a little bit of vandalism, a smattering of domestic violence, moderate levels of stress induced illness -- anything of this nature could conceivably reduce the settlement's productivity to the point of failure.

That failure could come quickly, for instance if sabotage resulted in a massive life support system failure or slowly, as might be the case if unrelieved emotional stress led to slightly decreased worker productivity, a small increase in carelessness, accident, vandalism, small scale pilfering, illness, etc., which in turn led to a little bit of red fiscal ink continuing over a sufficiently long stretch of time.

The point, of course, is that if we don't want our settlements to fail, we must consider ahead of time not only their physical, technological, mechanical, and logistical aspects, but we must also plan ahead to meet the spiritual, recreational, psychological, emotional, and intellectual needs of their inhabitants.

Humans don't function well in the long run without a certain sense of personal, familial, and societal security. How are we going to provide appropriate levels of security against personal failure, joblessness, hunger and homelessness, against injustice and brutality, mental and physical illness? What will we do with those who cannot be made to be productive -- the severely mentally or physically handicapped, the very young and the very old, those who cannot or will not forgo crimes of violence or serious social disruption?

Most humans don't function well in the long run under a cloud of unhappiness and discontentment. What can and should be done to minimize circumstances that increase unhappiness and what can and should be done to maximize circumstances that facilitate happiness?

Approaches

Some of these needs can find their fulfillment in reasonably satisfying jobs set in reasonably fair, safe, and pleasant work environments. But what system will there be to provide jobs and/or to provide for the needs of those who do not have jobs? How can we equitably and fairly match people to the jobs they need and at the same time match specific jobs to the individuals which would perform them best?

Some of these needs can be fulfilled through positive familial and friendship relationships. How will we see to it that the inhabitants of the space settlement have the time, energy, and opportunities to develop and maintain positive relationships? What resources and opportunities can be made available to facilitate socialization experiences?

Some of these needs can be fulfilled through a clearly articulated and reasonable canon of rights and responsibilities, protected and enforced with surety and justice. What should those rights and responsibilities be and how should the rights be protected and the responsibilities encouraged and/or enforced?

Some of these needs cannot be met except by the provision of inten*sive*, exten*sive* long term care and/or incarceration. Which brings us to another "-sive:" expensive. How will a space settlement afford such care? Or does the welfare of the settle-ment require that some or all such people be tossed into the life support recycle bin? I assert that conscience and the probable social consequences dictate that at least those who are not criminals receive a more humane solution. But if space settle-ment are going to provide long term care for those who are unable to be productive and for any who must be confined for the protection of the community, what are the most effective, efficient means of doing so?

If different individuals require different solutions for similar needs, how will that be discerned? Given the closed system/enclosed society nature of an early space settlement, and considering that some needs are best addressed by the society at large while others are dealt with more effectively by family, friends, neighbors, church, or other groups, how will we decide which are which and facilitate the effectiveness of those to whom the responsibility is given?

Who will govern the settlement? Should an Earth government have jurisdiction? To me it seems more than obvious that a space settlement must, at the very least, be semiautonomous, possessing and controlling its own local government. But is that a correct conclusion? And, if my conclusion is correct, what should be the form and the structural details of the government?

And what about laws and regulations? Should the definition of crimes include all and only those acts and inactions which are defined as criminal on Earth? Can every situation and how a space settle-ment community will feel about every situation be accurately predicted? Or will it be necessary to create a system by which the official codes of citizen rights and responsibilities can be adapted as the society adapts, changes, and evolves?

A lot of questions. And a lot that remain to be asked. Although I have seen a little scratching around the surface, I have never heard of any person or group thoroughly analyzing and addressing these issues. This needs to be done. The two most important tools for the survival and success of early space settlements will be appropriate life support systems and a complete social system (or set of systems) to facilitate humane, efficient, and productive human society. <RRR

A Century on Antarctica and what have we got?

Is this where we want to be on the Moon and Mars after our first century on those frontiers? Antarctica is a bad precedent we allowed to happen. We need to give a hoot.

Transportation: Ports & harbors:

none (offshore anchorage only)

Transportation: Airports: 18 (1997 est.)

39 locations with 33 having heliports. Runways at 13 locations are gravel, sea ice, glacier ice, or compacted snow surface suitable for wheeled fixed-wing aircraft; no paved runways. All are government operated except two facilities owned by non-governmental commercial tourist organizations.

Economy—overview:

No economic activity at present except for fishing off the coast and small-scale tourism, both based abroad.

There are no “on continent” facilities or installations in support of tourism

Causes of slow progress:

Through collective inaction, Antarctica has been abandoned to government activity.

Through collective apathy, a Treaty was agreed upon that serves as an extreme damper on economic activity.

APPENDIX

[from MMM #124]

Searching for Ready-Made Lunar Bases

by Allen G. Taylor, Clementine Project Leader
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In December of 1972, Gene Cernan lifted one foot, then the other, off the lunar regolith as he ascended the ladder into the Lunar Module. That was the last human contact with the Moon. Now, 26 years later, we are no closer to sending people back there than we were in 1961, when President Kennedy startled the world by setting the goal of sending a man to the Moon and returning him safely to Earth.

Sending humans to the Moon and returning them safely to Earth is still an extraordinarily expensive endeavor. It hardly seems a worthwhile thing to do, if the lunar explorers can only spend a few hours there, before their supplies start to run low, and they must return to Earth. In order for humans to play a useful role on the Moon, they must be able to stay for an extended period of time. To do that, they must have a place where they are protected from extremes of heat and cold, solar storms, micro-meteorites, impact ejecta, and cosmic rays. That kind of protection requires mass and low thermal conductivity. Transporting an adequate shelter from Earth would add a major fraction to the expense of just getting there. The best place to locate a lunar base is underground. The best way to excavate such a base is not to excavate one at all, but rather to use a cave that is already there.

There are caves on the Moon - "lava tubes". Early in its history, the Moon was very active volcanically. Lava flowed freely on the surface, forming tubes that roofed over and have waited several billion years for us to arrive and use them. The roofs of some of those tubes have collapsed, forming the rilles, some of which can be seen through telescopes on Earth. Sections of tube have remained uncollapsed, inviting us to come and take up residence.

The lava tubes that are visible to Earth-based telescopes might be too large to provide good candidates for lunar bases. Such lava tubes of large diameter need a great depth of overlying rock to keep from collapsing. Any intact large tubes would lie inconveniently far underground. Most useful would be lava tubes too small to be discerned from Earth.

The Clementine spacecraft, which mapped the entire surface of the Moon to an unprecedented level of detail in 1994, gives us a view of these smaller lava tubes. Over 1.9 million images in the visible, near infrared, and mid-infrared portions of the spectrum were captured.

The Oregon L5 Society has undertaken the task of finding and cataloging the small lava tubes in the Clementine dataset. Of particular interest are small sinuous rilles that contain interruptions which represent uncollapsed portions of a tube that has partially collapsed. Once cataloged, the candidate base locations can be examined more closely for suitability. Considerations would be proximity to resources, sites of scientific interest, or favorable locations for siting of a railgun satellite launcher.

Clementine captured images of the lunar surface in several spectral bands, spanning the visible, near infrared and long wavelength infrared. Collapsed lava tubes show up well in the visible part of the spectrum, given that the sun angle is suitable. Of the 1.9 million images taken, 620,000 were high-resolution images in the visible spectral band. Manual examination of even a significant fraction of those images is far too time-consuming to be feasible. Some form of automated search is the only practical way to thoroughly analyze such a large number of images in a reasonable time.

Lunar rilles are inherently difficult to characterize, making it difficult to teach a computer how to find them. Such geological features do not have a common form, or a characteristic diameter or length. Due to differences in topography, some have numerous sharp bends, while others are quite straight. Some appear in clusters, while others seem to be isolated from other rilles. These considerations make an automated search a difficult technical challenge.

A similar, but smaller scale problem was faced by researchers at the California Institute of Technology and the Jet Propulsion Laboratory in searching the Magellan radar dataset for small volcanoes on the surface of Venus. An adaptive recognition tool named JARTool was developed for the purpose of automated analysis of large datasets, and the Magellan dataset was used to test the effectiveness of the tool at recognizing target features, and rejecting features that might resemble the target features but that are not of the class.

The CIT/JPL team, led by M.C. Burl used JARTool to find volcanoes in 30,000 Magellan radar images that contain some 1 million small volcanoes. His team developed an algorithm that proved to be effective at identifying volcanoes, based on a series of training images containing volcanoes identified by geologists, that were presented to the JARTool before it was tasked with identifying volcanoes in the remaining images.

Our effort has adapted JARTool to identify sinuous rilles in the Clementine images of the lunar surface, particularly those with interruptions or gaps in the rille. We assume that such gaps represent uncollapsed segments of lava tubes. The goal of our project is to produce a catalog of uncollapsed lava tubes on the Moon. Researchers can then search the catalog for a wide variety of research purposes, including finding the best candidates for lunar bases, based on proximity to lunar resources, or areas of scientific interest.

JARTool was written on Sun workstations running the Solaris operating system. Mitron Corp. donated several surplus Sun Classics to our project, and Sun has given much needed technical support. This let us to get the project off the ground.

Now however, progress is seriously hampered by the slow performance of the obsolete Sun Classics. An up-to-date Sun processor would make a major difference in our ability to locate and characterize promising lunar base sites. Recently Sun has reduced the prices of its UltraSPARC 5 and UltraSPARC 10 processors. A new UltraSPARC 5 will cost $2400. Such a machine would improve our progress by at least an order of magnitude. We are currently seeking ways to fund the acquisition of an UltraSPARC 5 to move our project forward. If you have any ideas on how we might make such an acquisition please contact me at agt@transport.com. **<AGT>**

[from MMM #126]

Arctic History Shows Private Expeditions More Successful than Government Ones

Abstract of a paper* by Jonathan M. Karpoff
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http://papers.ssrn.com/paper.taf?abstract_id=145609

From 1818 to 1909, 35 government and 56 privately-funded expeditions sought to locate and navigate a Northwest Passage, discover the North Pole, and make other significant discoveries in arctic regions.

Most major arctic discoveries were made by private expeditions. Most tragedies were publicly funded.

By other measures as well, publicly-funded expeditions performed poorly.

- On average, 5.9 or 8.9% of their crew members died per outing, compared to 0.9 or 6.2% for private expeditions.
- Among expeditions based on ships, those that were publicly funded used an average of 1.63 ships and lost 0.53 of them.
- Private ship-based expeditions, in contrast, used 1.15 ships and lost 0.24 of them.
- Of public expeditions that lasted longer than one year, 46.7% were debilitated by scurvy, compared to 10.5% for private expeditions.

Multivariate tests indicate that these differences are not due to differences in the exploratory objectives sought, country of origin, the leader's previous arctic experience, or the decade in which the expedition occurred. Rather, they are due to systematic differences in the ways public and private expeditions were organized.

In particular, compared to private expeditions, public expeditions:

1. employed leaders that were relatively unmotivated and unprepared for arctic exploration;
2. separated the initiation and implementation functions of executive leadership; and
3. adapted slowly to new information about modes of arctic travel, clothing, diet, shelter, leadership structure, and optimal party size.

***"Public Versus Private Initiative in Arctic Exploration: The Effects of Incentives and Organizational Form"**

Jonathan M. Karpoff
University of Washington
February 26, 1999

Why hasn't Private Enterprise "done it?"
Perhaps because it seemss pointless to compete with an organization with bottomless pockets?
There has to be some leveling of the playing field.

[from MMM #127]

Revelations of Official NASA Cowardice during the Apollo 11 Mission

From the BBC: <http://news.bbc.co.uk/hi/english/sci/tech/newsid_390000/390634.stm>

"The first astronauts on the Moon would have been left to die in silence if they had been stranded by technical failure, according to documents just discovered." NASA had secret plans in place to turn off communications with Apollo if a glitch prevented the astronauts return. "Secret" as in secret from the astronauts.

[Commentary by Rich Brown]

Many things could have left Armstrong and Aldrin stranded on the Moon or in orbit after Apollo-LM separation. -- So tell me, what did NASA plan to do with Collins? Let him bob around in the Pacific unrescued? Go out and sink his capsule? He might have had some *choice* things to say if NASA cut off radio support and he made it back anyway.

[Commentary by Peter Kokh]

A government agency has the heavy burden of explaining tragedy to the public. We all recall the hesitancy with which NASA finally attempted to prepare us for what looked like an almost certain tragedy with Apollo 13. We remember the aftermath of the Challenger explosion and the real tragedy of gross and shameless cowardice exhibited by our increasingly risk-averse couch potato population.

After all, agencies and governments can't be heroes, only individuals can. And happily, a good fraction of commonplace individuals seem capable of rising to the occasion and demonstrating very great courage and humble heroism when that is the only split second decision that makes sense.

Thankfully, the occasion to "shut off the radio" did not occur during Apollo 11 or any other lunar landing mission. If it had, we would have been faced with more than the tragic loss of life, and the coverup by a cowardly agency. We would forever be tortured by not knowing how the stranded astronauts nobly rose to face their own impending deaths.

NASA may perhaps have been fearful that they would curse their fate, blame management, and "flip the bird" at the skies. But down deep, we all know better. Armstrong and Aldrin were (are) true men in the best sense of the world. Once it would have become apparent that there was no mechanical remedy for the situation, and no chance of rescue, they would have been disarmingly noble to the end. We might think that they would have been the ones that needed comfort. But I think *they would rather have been the ones comforting us,* making us promise that we would not abandon the dream, encouraging us as a nation to press on. It would have been epic.

The disturbing thing is that, apparently, NASA trusted neither the character of their astronauts, nor us! - PK

MMMC #13