"Expanding the Human Economy through Off-Planet Resources"

MOON MINERS' MANIFESTO

MMM Classics
The First Ten Years

Year 5: MMM #s 41-50
December 1990 - November 1991

MMM's fifth year began with the gift of a used Macintosh Plus from the Space Frontier Foundation. The actual donor who remains anonymous, had called to tell me how much he was enjoying each issue, but that the newsletter "*would look much better, if it were done on a Mac.*" I had been using a Commodore 64 billed as *"all that one could ever need!"*

Think of it, just 64 K of RAM. It was at the top when it came out. The Mac had 500 K and could be expanded. Yes it made a difference, and I would be a Mac man ever since.

Ape Cave left: a typical terrestrial lavatube, on the S flank of Mt. St. Helens, in Washington. The volcano erupted 10 years earlier. Lunar tubes are quite a bit larger in scale as gravity there is much lower. They are also quite a bit older In 1992, I would get a royal tour of the two Oregon Moonbase lava tubes just outside Bend, Oregon by two Oregon L5 members, Bryce Walden & mate Cheryl York.

[For fonts in these first Mac Issues, we used Geneva & **Chicago**]

We took up some new topics this year

- **Lavatubes** would become a frequent topic in MMM as they promised so much in the way of handy and voluminous ready made shelter. We began this coverage with a report on **Oregon Moonbase.**
- **Mars Direct** received one of its first promotions here in MMM, the article handed to me in person by Bob Zubrin.
- **Star*Bound** was a new series, not on how we might someday get to the stars, but about some specific locations and what they would be like.
- **Miniature Robots**, working as teams, was another new idea that received our attention.
- **"Plymouth"** was a new ABC-Disney science-fiction film in the making, and we were plugging its completion and airing.
- **The Lunar Frontier** continued to get regular attention with new articles illustrating what the pioneer life might be like; born-on-Luna children; funerals; naturally colored cotton; trees; effects of the long dayspan-nightspan cycle on culture,
- We serialized a paper on **Lunar Hostels** as low threshold starter bases that our chapter think tank had prepared for the 1991 ISDC in San Antonio. This paper introduced many new concepts such as the amphibious ***frog*** lander and the "donut" - a **hybrid-rigid inflatable module**, with an inflat-able torus surrounding a works-packed core that prefigured the TransHab architecture which in turn would be developed further by Bigelow Aerospace.
- **Biospherics** continued to receive our attention given all the publicity for Biosphere II.
- Life among the **asteroids** also got more attention.

MMM #41 - DEC 1990
An issue dedicated to Mars

IMAGINEERING MARS ROVERS

By Peter Kokh

When you consider the immensity of the challenge (Mars' surface area is equal to all Earth's continental land masses combined) present architectural strategies for constructing Mars Rovers, automated or not, NASA or industry, seem patently inadequate.

To spend some exorbitant amount of money creating a vehicle that can range only a few score miles from the landing site seems to imply pre-acceptance of an Apollo-like "science-picnic" scenario- we go, look around, and come back home, never to return. For *if we are serious* about opening up Mars for eventual human settlement, we *ought also to be serious* about designing **globe-ranging** vehicles from the outset.

What does that imply? Until we have graded highways cleared of boulders, wheeled vehicles are quite inappropriate. Most of the Martian surface, so far as we have explored it from our Viking Orbiters and Landers, is a continuous "strewn-field" - a 'Maginot' obstacle to wheels and tracked vehicles. While walkers would seem to be indicated, the ideas so far being put forth to make them self-navigating are absurd. Again, to spend millions developing anything whose usefulness will not extend beyond the limited scope of a first landing expedition - a radius of a few miles - is a waste of time. Self-navigation software that allows a vehicle to either wheel or walk at only a couple of hundred feet an hour is not what we ought to be spending our time on. What we need is a **Broken-Field Runner!**

JPL is testing a system using stereo cameras to provide 3D maps of the terrain ahead which the rover's computer will analyze to decide on the safest course forward, repeating the process every 15-25 ft! Can you imagine Olympic Games races on such a basis! WE NEED a heuristic software program that will allow the Rover to learn from experience, gaining confidence and speed. No human runner, negotiating an obstacle course, ever proceeded on the basis JPL proposes.

A good software program would allow a Rover, walking of wheeled, to recognize generically familiar patterns, attention focused *only*, and timesavingly, on the SIGNIFICANT differences AS they pop up. This, certainly, is how we do it - often even below the threshold of consciousness. Now a proper program designed in such a manner may make for slow learning at first. But there is no reason why a heuristic Mars rover can't do most of its learning right here on Earth in 'Marssimilar' terrain! Once on Mars, it would have to go slow for the first few moments while it adjusted its reaction patterns to the different gravity level. If all this is beyond our current level of expertise in Artificial Intelligence expertise, then perhaps we ought to set this project aside - until we are ready to do it justice. Why spend millions only to create some quaint anachronism which is more likely to grace some dusty museum hall than the dusty plains of Mars?

If *suitability for Global Mars Access* is to be our faithful guide, surface contact rovers, whether wheeled or legged, should not be the only option we explore. Even though Mars' air is rather thin, we should be able to engineer **ground-effects skimmers** - especially if they are equipped with hydrogen-filled buoyancy bags to neutralize most of the weight. (Hydrogen cannot burn in the carbon dioxide atmosphere of Mars). "Skimmers" would provide a swift means of personnel and cargo transportation by route of choice over a large percentage of the Martian landscape. Personally, I cannot see the sense of sending an expedition to Mars not so equipped. Skimmers could range in type from 'jeeps', to buses, pick up trucks, even analogs of our "18-wheelers".

Skimmers would free the opening of Mars from the Roman precedent of prior construction of a network of trunk roads. Bottled Methane and Oxygen, processed from the air, could run their engines, re-releasing Martian air as exhaust, and perhaps saving the steam.

Space enthusiasts should continue to be very suspicious of unnecessarily self-limiting schemes for Mars exploration. As the old saying goes, *anything worth doing, is worth doing right.*

RETHINK MARS SAMPLE RETURN!

Commentary by Peter Kokh

We definitely do need to know more about the chemical and mineralogical composition of the Martian surface along with the geological heterogeneity with which such potential resources are distributed. And we should have this knowledge in hand BEFORE we launch a crewed expedition! But is the Mars Sample Return Mission the way to gain such knowledge? We think not.

First, unlike the Moon, Mars is much more diverse from place to place. One or even a few sites sampled for return to Earth would give us a very skimpy knowledge at best. Rather we should launch a Mars ORBITAL Retrieved Sample Examination LAB (or MORSEL) to which a whole FLEET of surface samplers could send their troves. *Better to sample more areas, examining them in Mars Orbit, than fewer areas, sending the samples all the way back to Earth.* A greatly reduced sample bag of tagged soil and rocks defying analysis or yielding enigmatic results could then be sent to Earth after the great bulk of the samples had been satisfactorily characterized aboard this automated orbital pre-examination facility. This would also supply a "ground truth" calibration check.

If we can't yet build such an automated lab, let's start brainstorming now. how to go about doing so. MORSEL would give us a more adequate picture of Mars.

LUNAR DEVELOPMENT AND MARS

Commentary by Peter Kokh

If some would ignore the Moon, it is in our deepest self-interest not to return the snub. No one should put all their eggs in the same basket - here we are referring to building the LUNAR ECONOMY on the sole foundation of supplying energy to Earth, through either or all current scenarios: Solar Power Satellites in GEO, Lunar Surface based Solar arrays, or a Helium-3 harvesting operation for future fusion plants.

If one's sole goal is to build space colonies as a *by-product* of Solar Power Satellite construction, what ultimately happens to the Lunar Economy may seem unimportant. But *we* think that reaching a stage of healthy self-sufficiency for the Lunar Economy is probably the best choice of granite out of which to carve the cornerstone for a truly CIRCUMSOLAR civilization. If *this* viewpoint is on the mark, then it becomes rather *important to DIVERSIFY* the Lunar Economy. Serving the needs of pioneers opening Mars, is surely one such promising avenue for expansion.

Mars itself has nothing to sell the Earth except tourist meccas for the obscenely wealthy. Its moonlets, Phobos and Deimos, most likely are well endowed in the volatiles the Moon lacks. And any developing Lunar Settlement will be steadily acquiring the capacity to self-manufacture the more weighty of its needs to keep its trade balance with Earth as favorable as possible. It will be just such items that the Mars Settlement will need also and which the Lunans can supply at a definite fuel=cost advantage over similar items from the Earth's gravid surface. It is a two-way trade natural.

Until the Martian Settlement develops a diverse enough industrial base to shun trade altogether and turn in on itself - something the Moon happily will never be able to do - the more Mars' economy grows, the more the Moon's economy stands to grow in linkage.

The same is true vis-a-vis the Asteroids. The Moon, with a gravity well shallower than either Earth's or Mars', and with shorter synodic 'windows' to the asteroid belt than Mars, is much better situated than either Earth, LEO, or Mars to serve as the major outfitting and supply base for efforts to exploit the promised wealth of the asteroids, Earth-approaching OR Main Belt. The more the rest of the Solar System is opened up, the more the Lunar Economy should grow.

Mars *should fascinate* would-be Lunans! - PK

TEMPTATIONS TO ECO-CARELESSNESS

Commentary by Peter Kokh

Paradoxically, there will be little room for Lunatics and Lunacy on the Moon. Our biospheres on that desolate globe must be fully closed for economic reasons grounded in the need to import three of the four elements most essential to life: hydrogen, carbon, and nitrogen [oxygen being abundant on the Moon]. Not to religiously recycle "exotics" would be prohibitive.

When we get to Mars, the settler pioneers can expect a reprieve of sorts. The thin Martian atmosphere, with just 1/140th of Earth's atmospheric pressure, can yet be "mined" by well-known means to produce water, an Earth-normal air mix for habitat pressurization, and even oxygen/carbon monoxide and oxygen/methane fuel combinations to run vehicles, generators, and other equipment.

This undeniable head start advantage towards self-sufficiency has fooled many. The inventory of indigenous raw materials is not the whole key to economic self-sufficiency. If it were, Japan would be one of the World's poorest countries. The point is that Mars has nothing but tourist spots to market to Earth in exchange for those things its infant industries can't yet produce for itself; whereas the volatile-impoverished Moon has the far more important triple pluses of *"location, location, and location."*

Nonetheless, the *Rusty Dusties* pioneering the mountain slopes, canyonlands and plains of Mars will find themselves tempted to exhaust their pollutants to the outside atmosphere and soil, since fresh replacement atmosphere and water is, relative to the harsh lunar experience, so cheap and easy to re-process from the generous surroundings.

Atmospheric winds will sing a siren song: "We offer an inexhaustible sink for your cares." Dirty water will freeze, not mixing with the pristine permafrost from which fresh water is drawn (one of the water options.) We are so few, our settlement so small, and yet Mars is so big! What can it hurt?`

Even James Lovelock, of Gaia Hypothesis [1] fame, suggested in another book, The Greening of Mars, [2] that we use abandoned military missiles, ganged together to provide the necessary staging and delta-V, to rocket to Mars all of the stockpiled chlorofluorocarbons (CFC's) that we dare not use up on Earth if we don't want to destroy the last vestiges of the Ozone layer. On Mars, where we can't breathe the air anyway, and where there is no ozone to destroy, a CFC greenhouse effect would be most welcome. Fine! - *if* we are *never* going to *"terraform"* Mars! But if we are to leave open such a possibility for later more populous and capable genera-tions of Martians-to-come, had we not best be careful about rushing down some potential *cul-de-sac*?

Dire prediction: *IF* Mars is settled *directly* by Earth folk laden with bad habits, instead of by seasoned Lunans living right, eco-disaster will occur.

References:

[1] **Gaia: A New Look at Life on Earth** by James Lovelock 1979, 1987. [2000 edition: Oxford University Press, ISBN: 0192862189

[2] **Greening of Mars** by Michael Allaby, James Lovelock [1985 Reprint edition Warner Books; ISBN: 0446329673]

<<< end EDITORIALS - PK >>>

TO INJECT A UNIQUE FLAVOR INTO MARTIAN SETTLEMENT CULTURE, ADD THE ROMANTIC TOUCH OF OLD

BARSOOM

By Peter Kokh

When European settlers first arrived in the Americas, they brought many place names with them: (New) York, Boston, Norfolk, Birmingham, Cartagena etc. They reached into the pages of antiquity for other names: Memphis, Cincinnati, Atlanta, Phoenix. But often enough, they were quite content to adopt native names for places, or Anglicized versions thereof: Seattle, Tacoma, Chicago, Milwaukee, Chattanooga, Wichita, Quito, Mexico, Bogota etc. Using Indian names not only helped cut ties to the various motherlands, but gave the New World a special flavor.

When and if settlers come to Mars, they will have an assist from the list of features already named by the International Astronomical Union following their identification on orbiter photo-graphs. In naming settlements, they can refer to such pre-named natural features as a starting point e.g. Marineris Heights, Port Pavonis etc. They can also use baggage-names from Earth: New This and New That. But to supply "Mars the World" with that special colorful indigenous touch?

While native Martian names are not available, strictly speaking, Mars *has been previously populated* in various romantic Science-Fiction novels and in the pseudo-scientific overreachings of **Percival Lowell** and his many followers. If we build aqueducts to bring melted polar cap ice to the equatorial zone, why not assign them romantic names from Lowell's list of imagined **canals**?

Perhaps the most elaborate fanciful glimpse of Mars was that of **Edgar Rice Burroughs**, the creator of Tarzan, who wrote ten or more novels about *BARSOOM* over a thirty year period from 1911-41. What harm could there be in immortalizing some of his Barsoomian city names and names of his heroes, heroines, and villains?

In a planet of unrelieved ocher, rust, red, orange, pink, salmon, and coral shadings, a little literary color would be most welcome - a helpful assistance to the pioneers in seeking to establish a new collective identity, a symbolic declaration and reminder that "This is *not* Earth!"

Here are some of the Barsoomian city names which might be lifted out of fiction and into reality: the most famous, the twin cities of **Greater** and **Lesser Helium** (with their mile-high towers, pneumatic tubes, the great Avenue of Ancestors); then the storied *seaports* of old **Aanthor** (Avenue of the Quays, monoliths), **Hastor, Lothat, Thark**, and **Xanator**; other cities such as **Amhor, Duhor, Exum** (on the equator at the Prime Meridian), **Ghasta, Gooli, Horz, Illal, Invak, Jahma, Kadabra, Kamtol, Kobol, Korad, Manataj, Manator, Manatos, Morbus, Morgor, Onvak, Pankor, Phundahl, Ptarth, Toonl, Tjanath, Torquas, Zodanga,** and **Zor.**

Awaiting assignment to various real geographic features are the **Anatolian** Hills, **Dor** and **Otz** Valleys, **Ompt** and **Shador** Islands, **Korus** Sea, **Torquas** Mountains, **Toonlian** Marshes, and **Omean** subterranean aquifer-ocean. Names ready-made for regions or districts are **Domnia, Dusar, Gathol, Jahar, Jahma, Kaol, Okar, Marentina, Masena, Panar, Raxar,** and **Warhoon**. A circum-Mars equatorial highway or mag-lev route, could take the 'old Barsoomian name' for equator: **Polodona**.

For **Phobos** the name pool includes: **Thuria, Ladan, Ombra**, and **Tarid**. For **Deimos: Cluros**.

Young settler girls could be given, or take, such names as **Dejah** (the famed Dejah Thoris), **Haja, Janai, Lano, O Ala, Olvia, Ozara, Phao, Rojas, Sanoma, Sharu, Sola, Tavia, Thuvia, Ulah, Vaja, Vantija** and **Vanuma.** Young pioneer boys: Carter, **Carthoris, Djor, Floran, Gahan, Hovan, Jat Or, Kantos, Kulan, Lum Tar, Notan, Orm-O, Parthak, Ras, Sovan, Talu, Tars, Torith, Turan, Turjun,** and **Vandor** - *villains excluded.*

If special plants are bio-engineered to thrive in Mars' climate some "local" names out of Barsoom's "past" are **gloresta** and **pimalia** flowers, **mantalia** and **umpalla** shrubs, **sompus** and **usa** fruit trees; and the trees **skeel** and **sorapus.**

If for pets, settlers breed novel varieties of cats, they might call them **banths, komals,** and **soraks.** New dog breeds could include **calots** and **woolas.** A new bird, the **malagor**. Large designer animals can be named **orluk, thoat,** and **zitadar**.

When the Mars Republic issues its own currency, it could be called the **tanpi**. And *ready now* to be instilled with life is the much-described *Barsoomian chess game*, **Jetan**, played on a board of 10x10 orange and black squares with dwars, padwars, panthans, princesses, thoats, warriors. Less defined is a game of chance called **Yano** in which small numbered spheres are rolled across a board with numbered holes.

Future Martians will develop their own fresh frontier customs. Taking cues from Burroughs' Barsoom, they might include: special remembrances of their ancestors, the exchange of armlets upon establishing friendship, laying of hand(s) upon another's shoulder(s) in greeting instead of shaking hands. "**Kaor**" could replace "hello" and "Good Day". At parting, goodbyes might be signified by hand(s) above head, palm(s) backward. And at weddings, the spouses-to-be might exchange gold ceremonial collars.

A regional governor might be called a **Jed**. If there is a chief planetary executive, his/her title might be **Jeddak/Jeddara**.

We'll certainly use the thin air of Mars for transportation, but the Martian planes or flyers will look like strange caricatures of those plying Earth's skies, their design driven by different ambient conditions. A small flyer design can be called a **pinaar**; a large airliner a **vanator**.

In seeking to establish a separate identity, the immigrants to Mars can either start from scratch or borrow from the imaginations of past writers. ***A touch of old Barsoom would help!***

[* For more colorful tidbits, see John Flint Roy's 1976 **A Guide to Barsoom**: The Mars of Edgar Rice Burroughs - Ballantine, ISBN 0-345-24722-1-175] <MMM>

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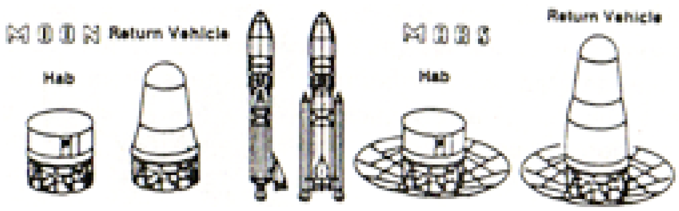
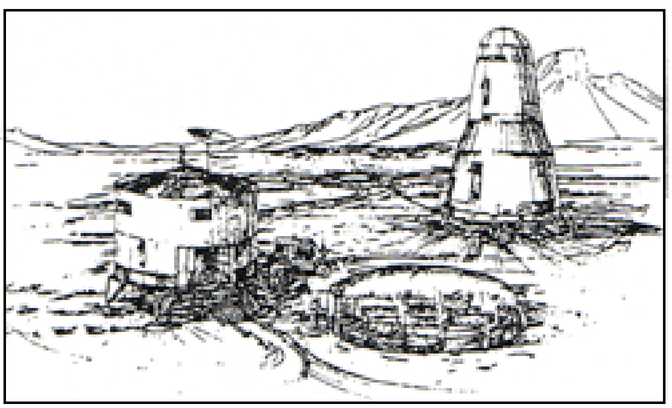


ELEMENTS FOR DIRECT MOON/MARS MISSIONS

[See the feature report on the Zubrin/Baker plan below] This bold plan recognizes the planned NASA Space Station as a roadblock for deep space missions instead of the asset originally intended, and is a first major effort to design a "stationless" mission scenario that promises both to radically cut mission costs and to dramatically shorten realistic timetables for their realization.



MOON MARS DIRECT →

With but a pair of shuttle-derived "Ares"vehicles, and bypassing a yet unfinished space station, a habitat base with a crew of four could be delivered directly to the surface of the Moon or Mars, following arrival & checkout of the return vehicle.

A Report on the widely circulated paper
by **Robert Zubrin** and **David Baker**,
of Martin Marietta Astronautics, Denver, CO.
With commentary [*] by Peter Kokh for MMM.

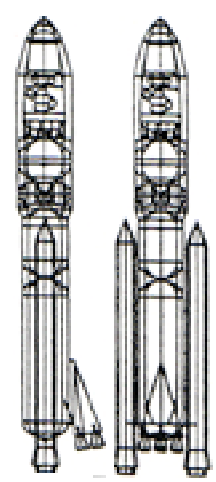
[* Cf. "NIMF: Nuclear rockets using Indigenous Martian Fuel" by Robert Zubrin in MMM #30, November 1989.]

[According to a bold plan that dares to sneer at the time-honored wisdom which holds that the way to mount any major human deep space mission is to assemble and fuel large craft in the "yards" of a low Earth orbital depot (the architects of Space Station Freedom having preempted the troubled and yet unbuilt facility for "downward" looking functions) we can send a ready-to-use Mars Base and an Earth-return craft "direct", that is Earth-surface to Mars-surface. No expensive and sure-to-be-further-delayed staging or transfer facilities needed in orbit around either planet! The conventional scheme of multiple "nodes", each of which by Murphy's law becomes a major buck-sucking undertaking further delaying the realization of the goal, must be set aside if we are to make up the time lost in short-sighted detours serving the non-germane purposes of those staying at home.]*

The Zubrin-Baker plan is based on their concept for a shuttle-derived heavy lift launch vehicle, **Ares**, an "in-line" rather than side-mounted configuration using the shuttle External Tank, advanced strap-on boosters, and space shuttle main engines (SSMEs).

[Ares was the ancient Greek god of war, commonly identified with the Mars of the Romans.].*

[NEWS FLASH: Washington DC, JAN 2, '91: NASA and the U.S. Air Force have agreed to combine their separate Heavy Lift Launch Vehicle programs. NASA had been working on the Shuttle-C (C for Cargo) concept which simply replaced the orbiter with a side-mounted cargo pod equipped with SSMEs. The Air Force had been working on its Advanced Launch System (ALS) concept. The agreement calls for a top-mounted or in-line configuration using the existing shuttle External Tank, and 4 to 6 ALS engines strapped underneath (but SSMEs if the ALS engines are not ready by the end of the decade). NASA and the Air Force will seek combined funding for the project which is at the top of the list of Congressional space committee priorities. A 1998 maiden launch is the target. A name for the new HLV was not announced. - Source: Space News Jan 7-20, 1991.]*



Ares Vehicle: Payload capabilities in metric tons (2200 lbs = 1000 Kilos)

- trans Mars 47.2
- trans Lunar 59.1
- LEO 121.2
- Height(m) 92.3

Ares Launch Vehicle Definition

So doing away with "grade-crossings", let's hold on to our hats as we enter the 'Mars Expressway.' In DEC '96 [Zubrin-Baker timetable prior to the announcement above] an

Ares lifts off from Cape Canaveral and fires a 40 metric ton unmanned payload off on a direct trajectory to Mars, where it aero-brakes into orbit and lands 8 months after leaving the Florida beach. The payload consists of an unfueled 2-stage ascent and Earth return vehicle. The craft is equipped with methane/oxygen engines that can be fueled with propellants produced from the Martian atmosphere.

[* "methanox" engines or even "**oochie**(s)" (for O_2/CH_4)? If such engines are to become the work-horses of the Martian frontier, surely we'll need some less cumbersome way of referring to them!]

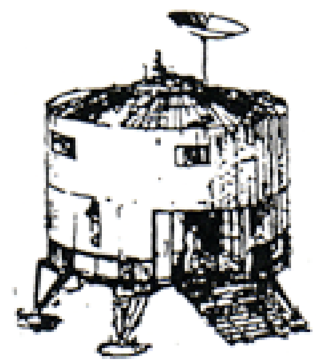
The return-craft has a life support system and is stocked with enough whole food to last four people 9 months, plus some dehydrated emergency rations. The Mars-bound cargo lists 5.8 tons of liquid hydrogen, a 100 kWe nuclear reactor, mounted in the bed of a small methane/oxygen internal [fully!] combustion driven un-pressurized utility truck, a small set of compressors and automated chemical processing unit, and a few small scientific robotic rovers. [Illustrations pp 1, 2]

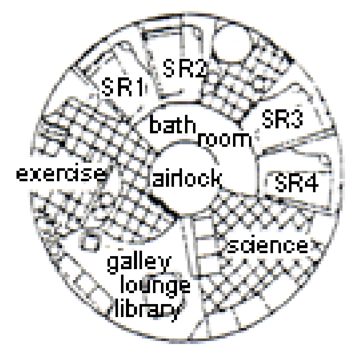
As soon as this payload is landed, the reactor is driven a few hundred yards away from the landing site and lowered off the truck into either a natural depression in the terrain or one created by the robots (teleoperated with frustrating slowness from Earth) with the aid of a few sticks of dynamite. The walls of the depression serve to shield the reactor from the base as a whole. The reactor's radiators are then deployed and a cable run back to the lander. Then the reactor, which has not yet been used, is started up to provide 100 kw of electric power to the site facilities. Compressors are then run to acquire carbon dioxide out of the Martian atmosphere. With the help of a catalyst, this CO_2 can be made to react with the 5.8 metric tons of hydrogen cargo, transforming it in a few days into 37.7 metric tons of methane and water. Next the chemical plant electrolyzes the water into hydrogen and oxygen. The oxygen is stored as a liquid and the hydrogen is reacted with more CO_2 to create more methane and water, and so forth. Additional oxygen is produced by directly decomposing atmospheric CO_2 into oxygen and carbon monoxide, storing the oxygen and dumping the CO. In the course of a year, about 107 metric tons of methane/oxygen propellant is produced.

[.While there IS hydrogen in the form of water vapor in the tenuous Martian air, it would take a lot of energy to extract it, which is probably why Zubrin and Baker feel it is cost-effective to bring the hydrogen from Earth. Eventually this costly import will have to give way to extraction of local water reserves, whether from the air, likely permafrost, or eventual conduits from the polar caps.] [* Oxygen and carbon monoxide would make an alternate, but less potent, "Martian" propellant combination.]*

[Zubrin and Baker do not spell out any parallel indigenous propellant production for an Ares-borne Moon Mission, but it might similarly start with an endowment of hydrogen brought from Earth, to be reacted with lunar silicon to produce Silane, SiH_4, a reasonably powerful analog of methane, to be burned with lunar oxygen. Not as powerful as liquid hydrogen, Silane yet stretches the punch of the original hydrogen endowment considerably. While this is a less straightforward production process than that ideal for Mars, it is doable all the same. Another, "all-lunar", possibility would be liquid oxygen and powdered iron fines.]*

If flight controllers on Earth are sure that the CH_4/O_2 propellant operation has produced its quota, then, during the January '99 Mars launch window, two more Ares boosters will rise from the Cape a few weeks apart. One lofts a squat cylindrical crewed <u>spacecraft-habitat</u> 27.5 feet in diameter (the width of the shuttle External Tank) and 16 feet high with a crew of four sharing its 600 sq. ft. habitation deck and with an additional deck for cargo. With aerobrake, landing fuel and ground car, it masses 38 tons and the Ares upper stage can project it directly onto a 6 month transfer orbit to Mars <u>without any fueling or assembly in Earth orbit</u>.



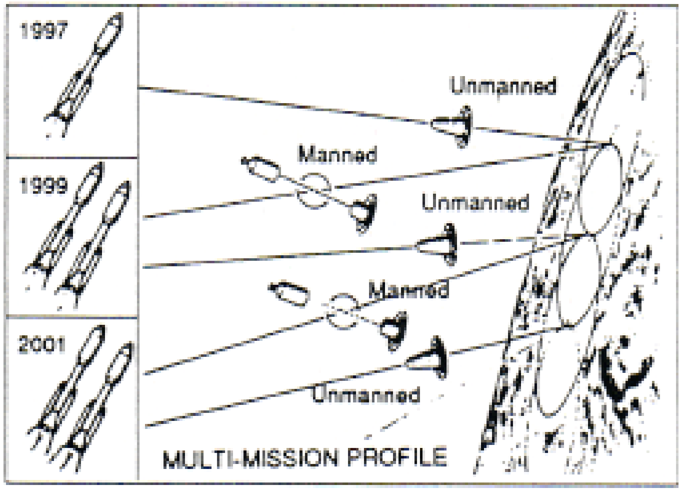


[150 square feet per person may be tolerable for the relatively short journey to Mars - especially if the crew is awake-and-about in two 2-person shifts - but it is far less tolerable than the 400-750 square feet of per person elbow-room space Americans prefer to carve out for themselves. But this small habitat, once landed on Mars (or the Moon), could easily double or triple its usable volume by the simple device of <u>inflatable side-wall pop-out additions</u> of "dumb" breathing room space - all with minimal weight penalty. This self-expansion could be to the benefit of both common and private space, with the increased morale boding well for attainment of the mission's goals. Such <u>prefab inflatable hybrid options</u> needs to be explored seriously.]*

The other Ares carries another return vehicle, identical to the one launched in '96, as insurance, in the unlikely event that the crewed habitat does not manage to land within rover-reach of the fueled and waiting first vehicle.

Once underway, the crewed habitat reels out on a 1500 yard tether from the launch booster which serves as a counterweight. The assembly is spun up at one rev/min to produce Mars level gravity (38% Earth-normal). On arrival at Mars, the combo despins, the booster is cut loose, and the habitat aerobrakes to the prepared site where the now already refueled ascent vehicle awaits. [See a similar idea in "The First Lunar Overflight Tours" MMM #21, DEC. '88 pp 3-5]

If the descent is reasonably on target, the second return craft is directed to a new site 500 miles afield, to prepare for a 2nd manned mission, during the next Earth to Mars launch window 19-20 months later.



During the 500 day [16+ months] stay on Mars, the 11 tons of prepared Methane/Oxygen propellant will allow the crew's pressurized ground car to take them some 10,000 trip miles at speeds over 20 mph in a series of sorties within a 300 mile radius. Or, by tapping the fuel depot at the new 2nd site, 500,000 sq. mi. (an area twice the size of Texas) could be covered by the first expedition alone.

For the return trip, the crew will climb into the methane/oxygen ascent vehicle and rocket back directly to Earth - without rendezvous and vehicle transfer in Mars orbit - a 6 month trip, but this time in zero-G. Both habitat and return vehicle have water-jacketed storm shelters in event of solar flares. Exposure for the three year saga is 50 rem.

[It will be important to have artificial gravity on the way out so the crew arrives fit to function. On the way back, with only leisurely debriefing ahead, maintaining muscle tone will be less vital.]*

[The Zubrin-Baker scheme is weak here. The Martian atmosphere does not provide sufficient protection against solar ultraviolet, solar flares, or cosmic rays and the base habitat, as sketched, does not appear to provide overall built-in shielding - that would be expensive. But exposure during the 3-season-long Mars surface stay can be greatly minimized by providing shielding for the entire crew habitat from Martian materials - see the following article, "IGLOOS, Shielding for Lo-Rem Martian Shelters".]*

With the arrival of the 2nd crew, a small rocket propelled flying vehicle will allow rapid crew transfer between Martian outposts [* important both to share talents and to provide a healthful change of scenery]. Introduction of nuclear thermal rockets [Zubrin's NIMF's would allow even larger cargo loads, and crew complements of 12 or more per flight. A few of these could establish the first permanent Martian settlement for a 100 or more hardy souls.

[* All of this IS doable at politically acceptable cost and during the schedule indicated. The first key is bypassing the troubled and delayed "down-looking" space station being optimized for non-depot functions. This is done by sizing mission components to the Ares *heavy lifter so that in-orbit final assembly or fueling is not needed. The second key is using only off-the-shelf shuttle technology for the Ares. The third key is that it the mission game plan similarly does away with Mars (or Moon) orbiting transfer nodes as costly and unnecessary infrastructure. The fourth key is that 80% of the mission hardware could concurrently support lunar missions, the aerobrakes used for Mars delivery being the principal item of difference.]*

[The appeal of Zubrin and Baker's plan is that it allows the micro-G people to keep playing their unpromising games, and gets on with the business of the REAL space frontier. It is* ***DIRECT FROM EARTH's SURFACE TO MARS' SURFACE*** *(or the Moon's). This may be the only real way out of the current financial quicksand into which the horse-blindered one-step-at-a-time people have gotten us.]* < MMM >

IGLOOS

ATMOSPHERE-DERIVED SHIELDING FOR LO-REM MARTIAN SHELTERS

By Peter Kokh

Mars, despite its precious endowment of thin atmosphere, has a surface almost as naked to the cosmic elements as does the Moon. True, this blanket of dry ice vapor [Mars atmosphere is largely carbon dioxide] does intercept and vaporize most of the micrometeorite rain from space. But it does little to temper the Sun's ultraviolet fury, a harsh fact of [non] life that constrains plans for someday "greening" those arizonesque Marscapes. In truth, even full-strength UV does not penetrate very far; glass, as most other likely building materials, can serve as an adequate barrier.

Of far more consequence, Mars' air is no longer dense enough to appreciably absorb or neutralize the all points bombardment of cosmic rays, nor the ionizing radiation from the occasional solar flare. As on the Moon, it will be prudent for explorers and eventual settlers to provide massive shielding for any and all human spaces, fixed or mobile, in which they will be spending significant portions of their daily routines.

On the much smaller Moon (half the diameter, one tenth the mass, and only 42% as gravid as Mars), the handy regolith, the blanket of impact-pulverized soil which covers the surface everywhere some 2 to 10 meters (yards) deep, can be heaped up over our pressurized habitats and passageways, and on top of vacuum-exposed workspace ramadas or canopies. The conventional wisdom has been that we will do something similar with the rock-strewn sands of Mars.

But this Moon-appropriate technique, while it does provide a fall-back option, is hardly the elegant choice for Mars! CONSIDER: 1) the windswept Martian surface may not have so universally uniform a regolith blanket. Indeed, Viking I and II surface pictures show rock and boulder peppered plains in which the sand grains may be no more than a filler. Gathering up fine material for shielding mass would be a much more difficult trick, leaving a probable rockpile surface in the source area. 2) Because of this, a larger area of the neighboring surface would have to be disturbed unless sand were to be "mined" from remote or out-of-sight locations,an inconvenience at least. 3) For both these reasons, automated deployment of surface-derived shielding in advance of the arrival of human occupants - should it be desirable to land and check out base-habitat structures in advance - would be much more difficult to pull off on Mars than on the Moon. It would even be a tedious effort for teleoperators based on nearby Deimos [Deimos stays overhead of any Mars surface location far longer than does fleeting Phobos].

So why not look for options? Fortunately, the atmosphere of Mars provides abundant raw materials for a number of alternatives Here is its composition:

COMPONENT	Formula	%age	Snows at °C
Carbon Dioxide	CO_2	95.32	-78.5
Nitrogen	N_2	2.7	-210
Argon	Ar	1.6	doesn't
Carbon Monoxide	CO	0.07	-199
Oxygen	O_2	0.03	-219
Water Vapor	H_2O	0.03	0

(& Neon, Krypton, Xenon, Ozone, parts per million concentrations).

Now conceivably, we could provide *a bladder of appropriate shape*, probably of serviceable Kevlar, to either drape over habitat structures directly or over an overarching framework under which habitat structures could be tucked safely *and fill the bladder with liquefied or frozen gases condensed out of the Martian air.*

<u>Voila! an IGLOO!</u> Its a nice thought, but one look at those freezing temperatures would seem to put a damper on the idea. Such igloo-type shielding would seem to require insulation and/or refrigeration if its regassification point lay well below mean ambient temperatures. Of the above selection, only *water* would remain frozen or liquid through the whole range of Martian seasons. Indeed, water would be ideal for, liquid or solid, it would buffer serve as an excellent thermal buffer between interior and exterior. No insulation would be needed on either the elements-facing or the habitat-facing walls of the containing bladder. This water-filled comforter could drape directly over habitat structures, avoiding the extra bring-along weight of a separate supporting framework.

Except in the case of possible research or ice-mining stations along the edges of the polar caps (and then it would make even more sense to use water-ice!), a *dry-ice or dry-snow* (CO2) filled bladder would have to be foil-faced on both sides and need to be separated from the shielded habitat area by some sort of trusswork, less it act as a heat-sucking sponge. Alas, Carbon Dioxide is more than 3,000 times as abundant as water vapor in the Marsair. In comparison, it would take a lot more up-front energy to extract the needed water, a debatable tradeoff with the rather significantly more forgiving maintenance required.

To be sure, if tappable permafrost reserves are handy to the chosen base site, the decision would swing towards water. Installation of the required equipment will most certainly require the presence of an on site crew, however. So the water-ice option, as attractive as it may be from an ivory tower perspective, presents great difficulties for the starter base, even more so if the base is erected in automated or teleoperated fashion prior to actual occupancy.

Yet if it is decided that it is too expensive to import the water supply needed for the explorers' (or settlers') consumption, hygiene, food production, and processing needs, and tapping permafrost reserves is deemed to be impractical in the near term, then by one manner or another, atmospheric water vapor will be the one remaining choice. In that case, the equipment needed to extract it must be included in the base setup cargo, as well as a power plant sufficient for the chore.

So much for a first blush assessment of igloo shielding possibilities! Now it's time to take a deeper look and do a little brainstorming. It *is not necessary to limit our choices to the gases actually present in Mars" atmosphere.* Other freezable volatiles can be produced out of these, such as Methane CH_4, Ammonia NH_3, and so on. And as we have read in the first article, methane production along with Oxygen and probably Carbon Monoxide, are high priorities for even the Mars Beach-head Base. Ammonia production, for use as a chemical feedstock for fertilizer etc., is a lower priority but will follow soon enough if any sort of permanent human presence is to be maintained on Sol IV. *Ammonia* liquefies at -33°C and freezes at -78°C, and would be easier to maintain in a non-gaseous state than Carbon Dioxide. Can we do better? That is, can we find a compound producible from Martian air a) with a much higher gasification temperature and b) in much greater potential abundance than water vapor?

What about the *oxides of Nitrogen*? Nitrogen itself represents only a 2.7% fraction of Marsair constituents, but add in some of the Oxygen which comprises a whopping 60.7% considered element by element, and the potential abundance of various oxides of Nitrogen might be much greater than that 2.7%.

OXIDE	FORMULA	%age	Gas above oC
Nitrous Oxide	N_2O	4.24	-88.8
Nitric Oxide	NO	5.78	-151.8
Nitrogen Dioxide	NO_2	8.87	+21.2
Dinitrogen Pentoxide	N_2O_5	10.41	+47

Paydirt!? It certainly looks as if either **Nitro-**

gen Dioxide (and the polymer N_2O_4 co-stable with it in the liquid state) or **Dinitrogen Pentoxide** which is a colorless crystalline solid (might need only a wind-breaker and not a full bladder!) could satisfy both of our conditions above. Isolated within the containing bladder, either would be sufficiently inert.

Consider too, that in the process of producing such oxides, appreciable water for other uses could also be produced as a by-product (2.9 kg of water per ton of N2O5 and 3.4 kg of water per ton of N_2/N_2O_4). As hundreds, even thousands of tons of these oxides might be needed, this water could be a valuable asset.

What are the potential drawbacks of a scheme to produce either Nitrogen Dioxide or Dinitrogen Pentoxide from Marsair for use as habitat shielding within a containing bladder? Obviously, it will come down to the relative ease or difficulty of the production process. Here on Earth, Nitrogen Dioxide is most economically prepared by reacting oxygen with Nitric Acid (HNO3 which by the way has a potential abundance of 0.2%, seven times that of water vapor, and liquid below 83oC) or by heating a heavy metal (lead) nitrate.

$$2\ NO + O_2\ \underline{\textit{to}}\ 2\ NO_2$$

$$2\ Pb(NO3)2 + heat\ \underline{\textit{to}}\ 2\ PbO + O_2 + 4\ NO_2$$

Under Earthlike conditions Dinitrogen Pentoxide is most economically prepared by dehydrating Nitric Acid with Phosphorous Pentoxide.

$$P_2O_5 + 2\ HNO_3\ \underline{\textit{to}}\ 2\ HPO_3 + N_2O_5$$

The salient task at hand is to identify and test out the most Mars-appropriate of producing either of these potential igloo-makers. If a practical process can be worked out, such igloo-shielding could prove quite attractive and work to accelerate Martian development. To recap, the advantages over sand-scrounging would be **a)** leaving the surrounding terrain undisturbed except for footprints and possible grading of roadways - a scientific plus and an aesthetic one too, **b)** ability to be put in place automatically prior to crew arrival, and **c)** its compatibility with production of valuable water reserves as a by-product.

To the writers knowledge, this is the first suggestion of using igloo materials for shielding on Mars. If not, it is at least arrived at independently.

<<< MMM >>>

Note: We wish to thank NASA scientist Geoffrey A. Landis for his response to this suggestion in which he points out that dinitrogen pentoxide is so unstable that it is classified as an explosive. Are there ways to stabilize it, possibly with some additive also produced from the Martian atmosphere? If not, we could simply use pure carbon or graphite powder, which in the absence of free oxygen, would not ignite or burn.

The advantages of atmosphere-derived shielding are considerable, and it would be a pity to drop this idea without exhausting all the options and alternatives. PK

LOCO *MOTION*

Mobility in Very Low Gravity Environments

by Michael Thomas, Seattle L5 Society

Space artists sometimes depict astroprospectors flying around an asteroid with a “Manned Maneuvering Unit” (MMU) strapped to their back. This image has tremendous romantic appeal, but assuming present technologies, is not very practical. MMUs do not have rocket thrusters, only jets of compressed nitrogen released through nozzles at relatively high pressure.

What has already been achieved with MMUs is remarkable, but the supply of nitrogen is their critical limitation. It does not go very far. A case in point is the Solar Max rescue mission, on which Astronaut George (Pinky) Nelson attempted unsuccessfully to dock with the Solar Max satellite. When docking failed, he tried to capture and despin the satellite by hand. Given enough time and enough tries, he might have succeeded in this daunting task. But the nitrogen supply in his MMU was running low already, so the attempt had to be aborted.

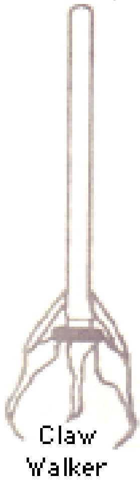
MMUs were simply not designed for such a demanding operation as despinning a satellite by hand. Nor are they designed for a 21st Century astroprospector to fly around an asteroid for an 8-12 hour shift. It is doubtful than an MMU designed for the shuttle program would last a single hour in this environment. So how are we going to get around? Clearly, thrusters will be of some use, but other methods of motion are needed for getting around in very low gravity (VLG) environments.

One of the Apollo astronauts compared walking on the Moon to a dog trying to run on a slippery floor. Even in the Moon’s 1/6th gravity, one does not have enough traction to easily walk in the normal sense. One is so light that one’s foot just slips out from under one. That’s why the Apollo astronauts had to hop on the Moon. When they touched down, for a brief moment, they had enough traction under their feet to push themselves forward again. But in a VLG environment, where the gravitational force is only 1/16th of Earth’s gravity or less*, hopping would be less practical. In one hop you could go hundreds of yards and reach dizzying altitudes. If you only wanted to go 10 feet, it would be very easy to overshoot your target. In some cases, it would be possible to accidentally leap into orbit, out into space. [Ceres, by far the largest asteroid, has a gravity of 3% Earth normal.]

There are two basic problems which must be solved. First, how to hold yourself down in the low gravity. And second, how to move yourself forward without any traction underfoot. Both of these problems can be addressed with very simple, practical techniques and tools.

If a craft is to actually touch down, or hover in co-orbital motion, cables can be launched from it with harpoons that are equipped to drive themselves into the surface and deploy barbs, to form a secure anchor. Ten personnel could attach safety tethers to the main cables and travel along the route of the cables. This is very limiting, as one can only go where the cables lead. Prospectors will need to move freely abut the surface and explore.

I am convinced that this can be accomplished by the use of simple equipment and hand tools, without developing any new technologies. A locomotion tool need only hold one down near the surface and move one forward at a reasonable speed and with reasonable control.

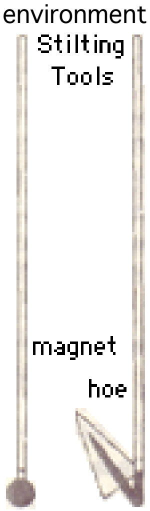


Traveling short distances in an upright position could be accomplished with a pair of tools I call "claw walkers." One would be held in each hand and one would be thrust into the surface and closed, rather like a post hole digger,while the other is firmly anchored. Then the one in the rear would be removed, moved forward, and thrust down again. This use of the tools as self-anchoring walking sticks would allow one to move forward hand over hand with ones feet on or near the surface.

The tool would be slow and awkward, but suitable for moving around in a small area. It's success also requires a certain density and compactness of the regolith. If the regolith has the consistency of styrofoam packaging beads (so loose that you could run your hands through it), this tool will not work.

Some people thought the Moon's regolith would be as loose as packaging beads before the landing of Lunar and Surveyor on it's surface. But it was very compact. And so the regolith of some asteroids may be relatively compact. While large impacts would tend to knock regolith off small bodies, so that it is kept loose when it falls back down, smaller impacts, which are much more frequent, would make the regolith settle to become more compact. Some compaction may also result from electrostatic forces as well. So a packaging bead like sea of dust on the surface of small bodies in not a foregone conclusion, and claw walkers may be useful.

Longer distances may be traveled in a VLG environment by "stilting", or moving with only one's tools in contact with the surface. This requires long handled tools that dig into the surface, making it possible to pull oneself down and forward at the same time, but mostly forward. Depending on the depth and density of the regolith, such tools might be hooks, hoes, or scoops, on long handles. For a body with little or no regolith, a broad scoop would be required to catch on the bedrock. For a body with very dense regolith, a how could be used to dig in and pull. And for a body with very loose regolith, a broader scoop would be needed. In the special case of a nickel-iron asteroid that is 50% or more metallic, an electromagnet might do the trick, and so would have to be turned off between steps.



Stilting tools should have very long handles so that the user would not be in contact with the surface most of the time. They would be hand held and their use would as much resemble rowing as walking on stilts. One tool would be swung forward and into/ onto the surface in front of the user. The user would then pull back on the handle to be launched forward (and slightly to the side to avoid gaining too much altitude.) When the tool was passing under and to the rear, the user would pull it up out of the regolith, which would help to keep him/her near the surface. At about the same time, the tool in the other hand would be thrust into the surface ahead of the user. While pulling the one tool back, the tool already behind the user would be swung up and forward in a circular motion, very much like rowing. This would allow one to travel quite rapidly across the surface of a minor planet, perhaps at 20 mph. One could stop by using one tool in the rear like a plowshare, to drag to a stop, while using the other in front, upside down like a ski, to avoid being slammed into the ground. Thrusters could be used if one strays too far from the surface.

<MT>

MMM #43 - MA R 1991

DAYSPAN

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

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

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

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

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

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

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

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

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

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

NIGHTSPAN

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

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

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

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

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

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

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

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

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

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

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

<<< MMM >>>

Will Lunans mark the days by the Month or by the SUNTH?

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

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

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

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

Meanwhile, not only will settlement life totally ignore terrestrial conventions out of practical need, but both exports and imports and the arrival and departure of tourists will pay heed to the local Sun angle (the time of sunth) rather than to the date on Earth. Business and accounting cycles for Lunan entrepreneurs will follow the march of sunths, not months. Even those businesses on Earth trading with the Moon will need to refer to the lunar calendar (or at the lunar phases shown on most 'normal' calendars) to help determine shipping times.

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

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

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

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

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

Another major question to be settled is whether all Lunan communities will observe the same weekend schedule, no matter how many 12o-wide 'date-zones' they lie apart from one another, or whether local weekends will fall with local sunrise and sunset. There are strong tradeoffs and *they* must weigh and choose.

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

I think it will be culturally refreshing! - MMM

Star*Bound *series continued (Not how, but where to?)*

This series began with "Brown Dwarfs" in MMM #40, NOV' 90

Alpha Centauri

Peter Kokh

Any Planets in this Twin Sun System would have some Strange Seasons.

[NOTE: All deduced statistics are those of the author.]

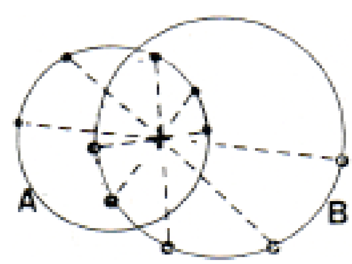


Fig. 1. **+** = center of mass or barycenter of system. A and B are always on oppo-site sides of **+** from one another in eccentric (0.52) 80 year orbits. The more massive A is always pro-portinately closer to **+** than B. Scale: 1 mm = 1 A.U. (= 1 Earth-Sun distance.

Most everyone knows that **Alpha Centauri** is the name of the "star" closest to our Solar System (if you except its dim, distant, and insignificant companion **Proxima Centauri** a so-what light month closer). Not everyone knows that Alpha is really two stars, not just one, which circle one another around a common center of mass or barycenter - a "binary system".

For decades, Alpha Centauri was THE first stop on our road to the stars - for science fiction writers. But this unquestioned common wisdom has changed in the past generation, as writers paid more attention to what astronomers had to tell us. More than a third of the stars in the neighborhood of the Sun - and we must assume this is typical - have one or more companion stars in orbits ranging from close in to quite far out. It *seemed* obvious that planets would have a hard time forming and maintaining stable orbits in such binary or multiple star systems. Accordingly, we supposed that the process of condensation from the protostellar cloud had two forks. One path must lead to a single central star with a retinue of planets, the other to binary star systems without planets. Alpha Centauri was then dismissed as an unsuitable destination - we were sure there could be no planets to visit, much less to colonize.

The interest shifted to reasonably sunlike stars of the single persuasion. Alas, even the closest of these lies considerably more distant. Alpha Centauri is 4.3 light years away, 9,000 times as far away as Neptune, 270,000 times the Sun-Earth distance, and 100 million times as far away as the Moon. The closest marginally sunlike solitary star is Epsilon Eridani at 10.7 light years. Much more like the Sun is Tau Ceti at 11.9 light years. Tau Ceti, and single solar type stars further out, now became the most mentioned Sci-Fi target.

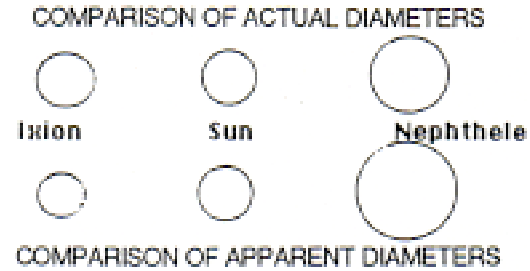
But as supercomputers were made accessible to astronomers, simulations showed that in some binary systems wherein either the two stars were quite close, acting gravitationally as one on surrounding space, or far enough apart so that appreciable space surrounding each was minimally disturbed by the other's gravity well, planetary orbits that would be stable over billions of years *were* possible. -*Caution!* That is NOT to say that it is now considered likely that planets *would* arise in such umbrella regions! At any rate, 'nearby' Alpha Centauri falls into the second of these 'favorable' configurations. So let's take a second look.

Alpha A and Alpha B revolve around one another in a very eccentric orbit once every 80.02 years. At their closest, they are 12.4 A.U. apart [1 A.U. is the mean distance of the Earth from the Sun i.e. 93 million miles or 149.6 million km]. This is about 25% greater than the Sun-Saturn distance. At their farthest, A and B are separated by more than 39 A.U. which compares with the mean Sun-Pluto distance. Simulations show that planets in inner system type orbits out to as far as Jupiter's distance (5 A.U.) would be stable around either of these stars. What more could one want?

The Name Game

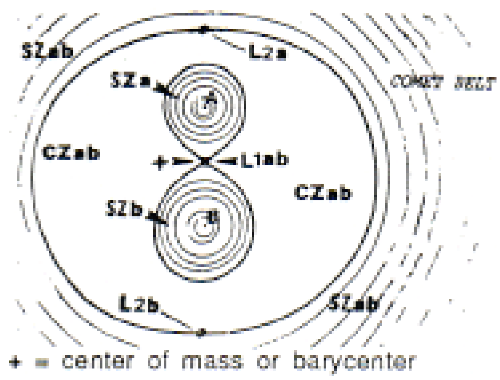
Before we carry our musings further, a word about names. First you may well wonder why the third brightest star in all the sky (after **Sirius** and **Canopus**) does not have a proper Arabic name. Alpha Cent. is so far south (-60 degrees) that it first clears the horizon, just, at about 29 degrees north. Simply put, out of sight, out of mind. But it does have a seldom used Arabic/Greek compound name: **Rigel Kentaurus**, in which Rigel means foot, i.e. the foot of the Centaur.

Now Alpha A is slightly more massive and brighter than the Sun, and Alpha B, though less massive and less bright, is nonetheless unrivaled until we get out to Tau Ceti. If there is even 'some' possibility that either or both have planets, shouldn't these two solar neighbors have names of their own? For the purposes of the discussion that follows, let us call them **Ixion** and **Nephthele** respectively, king and queen of Centaurs.



Ixion has 10% more mass than the Sun, shining 60% brighter. A planet placed around **Ixion** to receive the same amount of sunshine as does Earth (let's call any such planet a geophote) would orbit at 1.26 A.U. in 465 standard days. As **Ixion** burns hotter than the Sun, it may be slightly smaller in diameter and its yellow-white disk would appear smaller yet, in its geophote's skies. Let's call this imaginary world **Ixion III**.

Fig.3 Stable vs. Chaotic Orbits around Binaries



KEY: + = center of mass or barycenter.
SZa, SZb: Stable planet zones around A and B
SZab, CZab: Stable and Chaotic shared planet zones
L1ab:Theoretical shared mid-point jovian planet at +.
L2a, L2b: Outermost possible unshared planets at "inline" opposition points where they would have periods identical to the system's. [here, 80.02 yrs at distances comparable to Uranus-Sun from both A, B.]

A geophote around the dimmer Nephthele would orbit in 238 days at 0.67 A.U. (about the distance of Venus from the Sun). As Nephthele burns cooler than the Sun, it is less dense and its yellow-orange globe is half again the Sun's size, looming twice as large to its nearer geophote, which we'll call **Nephthele II.**

Before you get carried away imagining what seas and continents grace these hypothetical worlds and what sort of life might have arisen there, consider this sobering fact. First, on Ixion III. At its dimmest, i.e. at its furthest point of the eccentric A-B orbit, Nephthele would appear to be only 1/3500th as bright as the sun (Ixion) but still the equal of 75 full moons, and it would creep slowly through the constellations at 2.3 degrees per local year. But when Nephthele was closest, and swiftest, covering 14.4 degrees per local year, it'd be 1/350th as bright as the sun, or 750 full moons!

Now Nephthele completes a circuit of Ixion II's heavens in about 63 local years. For years at a time Nephthele would shine to one side or the other of Ixion in the daytime sky *in a given season* . Then for many years it would blaze brightly in what would have been the nighttime sky *in that same season*.. If our Ixion III has an atmosphere, NO star would come out for years during that season (other than the twin sun) and it would never get darker than a very bright twilight.

Climactically, Ixion III could have a normal set of seasons if its axis is appreciably inclined to its orbit as is the case with Earth. However, *biologically*, these annual seasons *might* be masked by the "white night" seasons of the greater "Nephthelean year". No matter which numerical system hypothetical natives of Ixion III might have, their 'century'-like counter would be calibrated by Nephthele's circuit through its skies, i.e. pegged to 63 some Ixion III years. Culturally, "the Moods of Nephthele" would play as important a role - if not more important - than the yearly seasons.

Now on Earth, many species of plant and animal have physiological and behavioral patterns regulated by the succession of day and night. Analogous species on Ixion III would have to evolve regulatory mechanisms not confused by the changing pattern of nighttime light-seasons *shifting for each generation*. Earth has night-blooming plants, as well as nocturnal animals. It is difficult to imagine either finding a niche on Ixion III.

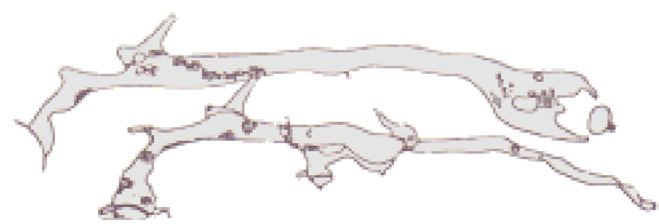
The most favorable pattern one could hope for, would have Nephthele at its closest and brightest during one hemisphere's winter 'nights' and furthest during that hemisphere's summer nights, and also find most of the temperate and tropical land mass areas arrayed in that same hemisphere, be it north or south. But that situation could be temporary in terms of geological time if the major axis of the A-B (Ixion-Nephthele) orbit slowly precesses. If so, that would pose even more formidable challenges to slow evolutionary adaptation.

A complex and disadvantageous setting to be sure. But the situation for our hypothetical Nephthele II is even worse. At its dimmest in that geophote planet's skies, Ixion, when most distant, would still be about a 1000th the brightness of the standard sun (here Nephthele), and equal to 270 full moons. At is closest and brightest, it would be 1/100th as bright as the sun, and the equivalent of 2700 full moons! When Ixion was above the horizon in what should have been night on Nephthele II, it would be as bright as a cloudy day.

As bad as this all sounds, we have analogous nighttime conditions in Arctic and Antarctic summers within the Arctic and Antarctic circles. But here on Earth, the pattern of "white nights" is the same year after year, presenting evolution with a fixed challenge. On either our hypothetical Ixion III or Nephthele II, the pattern would shift in 80 Earthyear cycles, presenting much more of a challenge for adaptation. If one or both such planets have indeed formed in our neighbor binary system, life would have achieved much if it only attained levels that we would call *very* primitive, and there would be no higher plants or animals, let alone 'native intelligence'. With no established advanced flora or fauna to intrude upon, human colonists might be able to nurture food plants and husband farm animals all brought with them from Earth, *in light-controlled enclosures*. But such plants and animals would have a predictably hard time establishing themselves in the wild well enough to survive through the many years of the local white night seasons. In such a case, the land outside the immediate settlement areas would remain pristinely raw and primitive. The settler culture would probably grow in complexity beyond Earthly precedent.

Our recommendation is to forget Alpha Centauri as a prime destination - *UNLESS*, through instrumentation and data enhancement techniques not yet achieved, we *do* discover that one or both stars in this system is a "sun" in its own right, i.e. that it/they have planets. I, for one, would be pleasantly surprised. Dream on, if you will, but don't bet your life savings on it! – **MMM**

MMM #44 – APR 1991



Site of the Oregon Moonbase: Young's Cave complex near Bend, Oregon, is a cross-linked pair of lava tubes. It has been thoroughly investigated for its potential to support simulated lunar base activities of various kinds, with many potential users. We report on this outstanding NASA-supported project of the Oregon L5 Society NSS chapter, and the prospects for future site development.

OREGON MOONBASE

With the help of a NASA Grant, 3 Oregon L5 Society chapter members have investigated the potential of a unique site in their geographic backyard to support lunar base simulation studies of various kinds.

Report by Peter Kokh

For wildlife, it must have been the depths of hell. Repeatedly, between 17 and 11 million years ago, tensions in the bowels of the Earth split the surface apart between the Cascades and the Idaho Rockies in what is now Oregon and Washington. Runny silicon-poor lava poured out of multiple fissures to form 2000o F floods of red death, as much as a hundred miles wide, advancing at an merciless pace, literally disintegrating animals large and small unfortunate enough to have made a misstep or taken a wrong turn or stumbled in a stampede or simply fallen exhausted from the endless urgent retreat. Such wholesale purges of the area's flora and fauna happened over and over in episodes typically 10,000 years apart, long enough to allow a teasing Sysyphus-like recovery.

In the process, old valleys and lower hilltops alike were buried under an accumulation of basaltic blankets up to hundreds of feet thick - an estimated total of 77,000 cubic miles (in comparison, Mt. St. Helens released 1/2 cubic mile of material). It is in this context that a number of lavatubes formed in the Bend, Oregon area, when rivers of hot lava within a cooling sheet drained out into lower-lying basins, leaving relic cavities behind. Similar features honeycomb the slow gentle slopes of Hawaii's great shield volcanoes, features likewise formed by runny pahoehoe lava (thicker more viscous lava builds up tall cones).

Some four years ago, just a month before the March 1987 L5/NSI merger in Pittsburgh, Oregon L5 chapter leader Bryce Walden, who had read F. Horz's article "Lava Tubes: Potential Shelters for Habitats" in the 1985 "Lunar Bases and Space Activities of the 21st Century" edited by Wendell Mendell, was present during a Young Astronaut tour of the Portland Air National Guard Base. He suggested a YA field trip to a lava tube near Bend, a proposal which was greeted with enthusiasm. After a chapter team visited many potential sites that spring, a simulation exercise was actually held at Skeleton Cave. The mission tested organization, design, logistics, construction, human factors, and educational opportunities. Included were a surface camp and a 'lunar base' 470 meters inside the cave. This consisted of a sleep/work platform, a communications desk, a galley, and a sanitation facility. Mission science included cave mapping, astronomy, geochemistry, and environmental monitoring. The city of Bend, properly impressed, then offered the use of Young's Cave, a site less visited and less disturbed by visitors and tourists. A third simulation was run there.

[The 12 acre Young's Cave site is owned by the U.S. Bureau of Land Management, but the City of Bend Dept. of Public Works holds the land patent as part of its wastewater treatment plant site, a half mile to the north. Bend has given Oregon Moonbase a 5-year renewable lease to the site for research & education purposes.]

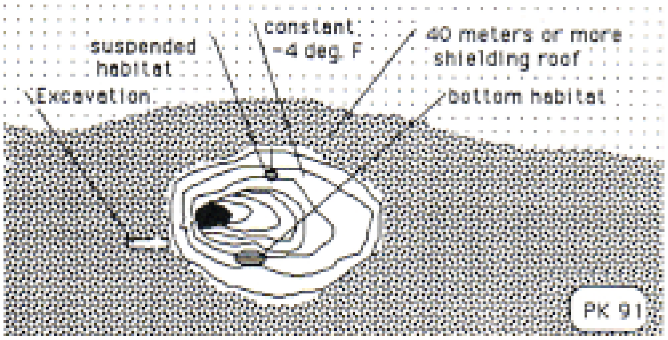
The following year, the Oregon L5 team, after networking with the AAAS, Lockheed Engineering and Sciences, and the Oregon Grotto of the National Speleological Society, began in depth research of the concept of an outfitted lavatube as a site for ongoing professional lunar base simulation activities of various kinds. After exploring many scenarios for use of lunar lavatubes, the team prepared nine proposals for NASA's Office of Exploration Innovation Outreach Program. The day after the 20th anniversary of the Apollo 11 Moon landing, NASA announced the acceptance of one of these: "Site Characterization of the Oregon Moonbase".

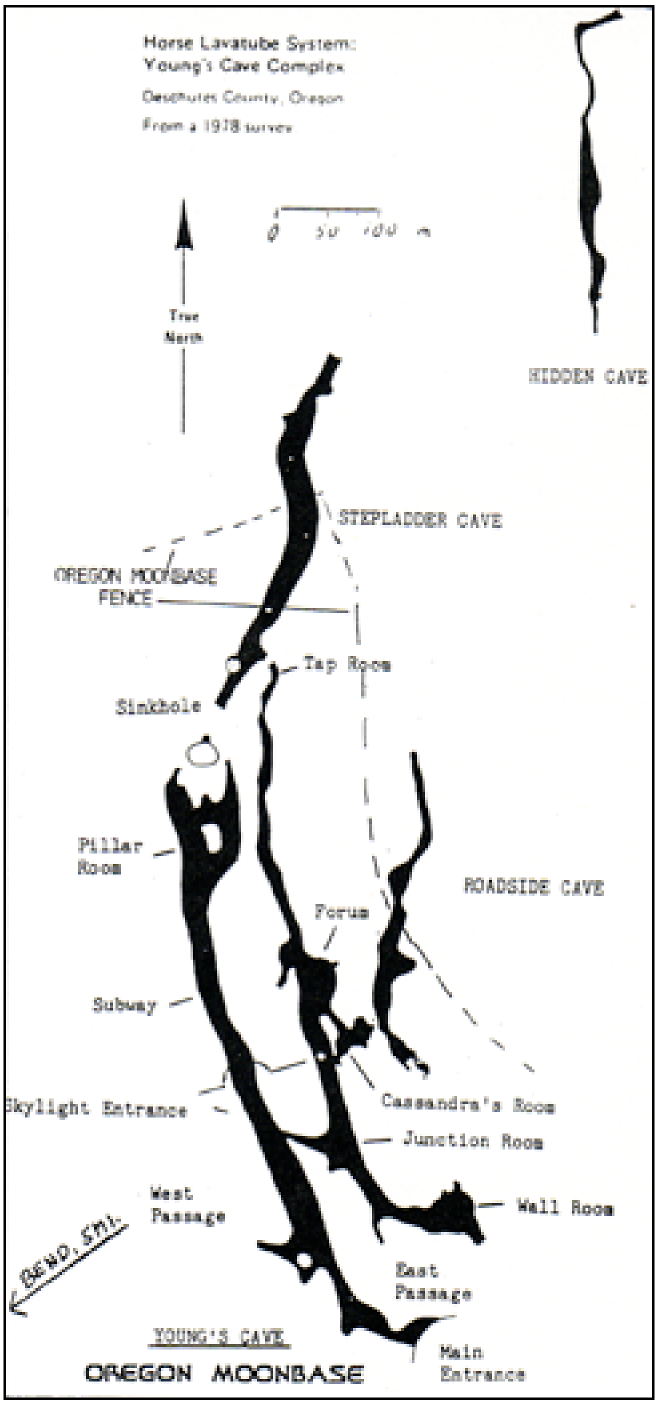
After months of contract negotiations, funding was received in March 1990. Meanwhile the team was busy publishing and networking, and circulating Users Surveys to 300 potential interested parties. [MMM/LRS received one of these and was intensely interested, but chose not to reply because there appeared to be no realistic scenario by which we could find the funds to use the site in any of the ways which occurred to us. Some of our suggestions, which apparently have not occurred to other potential users, are indicated near the end of this article.]

Terrestrial lavatubes are typically 10-30 meters wide and a few kilometers long at best. All indications are that their more ancient lunar cousins are more than an order of magnitude larger, 300-500 meters in width and height with 'roofs' 40 meter or more thick, and many kilometers long. There is every reason to believe the slopes of the great Martian shield volcanoes are laced with similar features on an intermediate scale. In any case we are presented with voluminous shelter from the cosmic elements (cosmic rays, solar flares, solar ultraviolet, most meteorites, and wild surface temperature swings).

These handy features have endured unused and intact for a billion years in the case of Mars, and for 3 plus billion years in the case of the Moon. In contrast, our typical limestone cave lasts only a few hundred thousand years in the context of Earth's active geology. Such places can offer primary shelter for lunar bases of considerable size, or ready room to grow, especially for the area-intensive needs of industry, agriculture, and storage. Too large to seal and pressurize, they offer safe haven for cheaper pressurized structures such as inflatables, and will allow those working within to wear lighter weight pressure suits instead of bulky hard suits, leading to a quantum leap in EVA safety for construction workers. The advantages are so clear, that it would be blind dead-end folly to deploy a major surface base without a suitable lavatube close at hand for earliest expansion. With such an option, the actual surface installation might even be kept minimal.

Lavatubes occur in the relatively flat mare (lunar "sea") areas, typically near to highland "coasts" thus providing a site where industry has access to both suites of materials. Possibly the only refuge from troublesome lunar dust (spallation debris on the tube bottoms will not have been micro-pulverized like the surface regolith blanket - Martian tubes may include wind and floodborne sands, even ice), lavatubes also commonly offer other handy features: roofs strong enough to support suspended structures like habitats and transport systems above uneven floors, handy sidewall benches, areas of level floor created by cooling pools, frequent mid-floor channels in which to lay utility service runs, etc.





For the purposes of executing the grant project, the Oregon Moonbase Team has been headed by Cheryl York (fka Singer) as principal investigator and includes Walden and Tom Billings as researchers. It next set about doing a thorough site characterization, essential before planning development of a facility that would support the sort of uses envisioned. Young's Cave was thoroughly mapped, the structural strength of its walls and roof assessed by an engineering firm. The surface area was also mapped and characterized. Geological, environmental, and archeological assessments were likewise contracted out to qualified parties.

Once popularly known as Kegger Cave, Young's Cave consists of two main East and West passages roughly 900 and 1100 feet long respectively, gently sloping only a few meters along this length. These main passages are connected by a low intermediate passage that is nearly blocked. Nearby Stepladder Cave, Hidden Cave, and Roadside Cave were evidently once part of the same complex but connectors have been blocked by lava plugs or sinkholes. These caves are part of a long system of lavatubes in the Bend area running in a general line from SSW to NNE. The cross-sections are generally semi-circular, the lower portion having been filled by a late flow (there were apparently multiple episodes) that did not fully drain.

The width varies, alternately pinching and swelling. There are areas of breakdown, some early, some recent, with scattered debris piles. There is a layer of sand fill deposited and rearranged by wind currents and water (both of which are absent on the Moon, but at work on Mars). The Geological survey was done by Stephen L. Gillett, a consulting geologist now in Carson City, Nevada. Steve is a member of Seattle L5 and long-time reader and sometime contributor to MMM.

Century West Engineering of Bend did the engineering analysis. A series of borings shows the roof to be generally from 10 to 20 feet thick with 7-19 ft of hard basalt overlain by 0-3 ft of loose soil. Except for a few transverse cooling cracks, the ceiling is relatively intact and rock quality analysis shows the roof should support from 2-60 tons suspended weight per linear foot, depending on the varying roof thickness and the presence or absence of fractures. For this purpose, a system of rock bolts will do. In some weak areas, roof-shoring supports are advised. There is an estimated 6000-7500 cubic yards of sand fill on the floor ranging from 0-6 ft thick as measured by a series of hand-auger holes. This could be removed, if desired, by vacuuming. Rock debris could be removed, if and where desired, by backhoe or by hoists through openings made in the roof, thereafter available for installation of equipment. The shape of surface terrain was also surveyed. Development of the future Oregon Moonbase facility may include some removal of sand and debris, stabilization of some weak roof areas, and some excavations into the basalt walls, floor, and roof.

The **USER SURVEY** was returned by 33 interested parties (out of 300 addressees). Proposed uses include simulations of automated and crewed Moon and Mars missions, expedition design, testing and demonstration of base systems and subsystems (shelter and habitat, life support, power and control systems, surface systems), resource development, geological and planetological studies, and education. Potential users include NASA, aerospace industry professionals, educators and consultants. Most users indicated the similarity to expected lunar & Martian conditions (verisimilitude) outweighed the remoteness of the proposed facility.

An analysis of user needs indicates "the proposed facility should focus on **two main areas: surface/subsurface/subsurface-equipment interaction** (construction and excavation techniques, transportation, access) and **integration**." Short-comings include the lack of vacuum and lunar 1/6th gravity, about which nothing can be done, and the lack of a lunar dayspan/nightspan cycle, which can be easily simulated underground as needed. As many groups wish to work with full-scale habitation and life-support systems, the facility must provide adequate support systems (power, water) upfront. Eventually, permanent habitation modules will be desirable for on-site housing of the user personnel. As the facility develops, the educational potential will grow with it, from YA mission simulations to public tours and professional seminars.

One whole suite of potential use seems absent from the gamut of suggestions contained in the returned user surveys: materials processing based on basalt. Even though the common basalt in this area is a less faithful analog of what we have found on the Moon than the Mid-Continent Rift basalts used as the basis of the standard Minnesota Lunar Simulant, useful work in crude processing methods could be done at this site. Working with low-tech (thus lunar-appropriate) Cast Basalt to fabricate a wide range of products (from tableware to performance-light structural elements) suggests itself. Based on materials research done on site and elsewhere, a visitors' center could be partially built (or expanded) and furnished with sample items to illustrate the possibilities for lunar base self-reliance to the public. A portion of the cave complex artificially illuminated according to a lunar dayspan/nightspan cycle could house a number of agricultural modules and bioregenerative life-support research and demo units.

The current ambition of the Oregon Moonbase Team is to develop and operate a facility in the wide **niche between highest realism/highest cost** (i.e. the Antarctic Dry Valleys) **and low realism/low cost** (i.e. the lab). Some of the work proposed for the site would actually not demand that faithful an analog to lunar lavatubes. Light cycle dependent work, for example, could be done in any appropriately sized limestone cave or even in a large hanger. Even so, the interaction between users at the Oregon Moonbase will confer a matchless advantage to doing work there.

Such an expenditure would be cheap insurance that whatever NASA, other agencies or even private enterprise eventually might deploy on the Moon or elsewhere will work as advertised.

A proposal has been submitted for **Phase One Development**, the minimum necessary to serve the least demanding potential users, and Phases Two to Four are in process of definition. Phase One will include a Facility Operations Center, a dedicated Teleoperations Center, a powerhouse, lighting systems, water heating and storage, food preparation and storage, general and hazardous waste handling, security and safety systems, plus access and communications systems.

All this will cost money, an estimated $6.2 millions over four years. But such an expenditure would be cheap insurance that whatever NASA, other agencies or even private enterprise eventually might deploy on the Moon or elsewhere will work as advertised.

We can only hope that "the powers that be" realize that this facility is not another luxury but an investment that fills an essential need on the critical path towards the realization of a spacefaring civilization, in accordance with the Space Settlement Act of 1988. It would be a good omen for all of us if the funds needed to begin Phase One development are forth-coming in a timely fashion.

Our hats off to the Oregon Moonbase Team. If all NSS chapters had people as dedicated and determined as this one, who could doubt that the realization of a spacefaring civilization would be guaranteed? While the natural endowment of their chapter hinterland provided them with this splendid resource and opportunity, this writer has no doubts that if they had not been so blessed, they would have found some other way to play a major role. Their work should inspire us all and demonstrates that there IS a place for chapter activity beyond the traditional roles of grass roots activism. **MMM**

[Speculation}

ICE CAVES

Possible Unsuspected Cometary ICE Cold Crypts Below the Lunar Surface

By David A. Dunlop and Peter Kokh

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

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

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

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

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

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

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

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

We may have won the Solar 'Lottery'!
But we'll have to wait to check it out.

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

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

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

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

EARTH-BASED SEARCHES FOR LUNAR LAVATUBES

Writing in <u>Starseed</u>, the newsletter of Oregon L5 Society, Oregon Moonbase researcher Thomas L. Billings discusses ways to search out lunar lavatubes. Tube openings are hard to spot by camera unless you are right on top of them. While intelligent lunar base siting will require better orbital mapping than provided for the Apollo landings, the best method may be to look *throug*h the rock. The severe dryness of the lunar surface should make this possible for orbiting radar. (Airborne radar has been used successfully to find lava tubes on the big island of Hawaii.)

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

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

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

[Star*Bound] *series continued*

More on ALPHA CENTAURI

By coincidence, the April issue of <u>Astronomy</u> magazine has an article on the possibilities for planets in the Alpha Centauri system, by Ken Crosswell. While carrying some information new to us (evidence that these twin stars are a bit older than the Sun) and using slightly different figures for mass and mutual separation, the writer reaches broadly similar conclusions. He gives a smaller diameter for B [Nephthele], and it is questionable whether he has taken into account its lower temperature and more diffuse illumination.

He is also much more conservative in allowing stable orbits only twice as far out as the Earth's distance from the Sun (i.e. 2 A.U.) to our 5 A.U. Let's agree with him that 'planets' could *form* only within the tighter range. Yet orbits for planetesimals or asteroids prevented from coalescing into a single body *should* be stable out to 5 A.U. Such an asteroid belt might contain significantly more matter than our own, with asteroids rather more closely spaced. This would probably result in impact-destruction of sizable bodies like Ceres, etc.

Out of his field, Crosswell's treatment of the potential biological problems is superficial and not to the point. While he is correct in saying the heat of either distant sun would pose no climate problems, he overlooks the potential for shifting seasons of 'white nights' to play havoc with biological rhythms. - PK. < **MMM** >

PROXIMA centauri

Or, the Saga of The "M-Wave"
By Peter Kokh

Last month, we took a journey of the mind to 'nearby' Alpha Centauri, finding it an unpromising goal. What about Proxima Centauri, Alpha A and B's distant companion (some-times designated Alpha Centauri C)? The actual separation is some 13,000 A.U. or about 75 light days so that Proxima [Latin for "nearest"] *could* have a full range of planets in orbits unperturbed by the beacon-bright twin stars in its sky. Ixion (Alpha A) appearing a little brighter than our full moon, Nephthele (Alpha B) a little dimmer. They would appear together in a fixed area of the sky, from 3-10 arc minutes apart at best, seasonally dominating the heavens. Proxima's orbit about them is so wide and slow, that this 'fixed' position would take about 3,000 years to drift a single degree. There are clues that Proxima may be only a billion years old, whereas Alpha Centauri A and B seem to be about 5 to 6 billion years old (a bit older than the Sun) so that Proxima may be a 'captured' companion. While 'white nights' wouldn't be a hurdle for biological adaptation here, it seems quite unlikely that Proxima could harbor a planet at 'geophote' range. - Consider:

Proxima, a dull red dwarf of class M5, isn't the dimmest star known (Wolf 359, an even duller M8 7.6 light years from us, can manage only a fourth as much light), but it does fall *in the lowest percentile* of true stars, those that shine with the light of nuclear fusion in their cores. In itself, that might make it an interesting star (or system) to visit. While planetogeny can hardly aspire to the level of science, given the current absence of data from any system but our own, it is possible to go out on a fairly sturdy limb and make these predictions [the writer's own]:

- Single stars considerably brighter than the Sun will have burned so hot in their youth before settling down to "main sequence" adulthood that nearly all gaseous matter will have been blown clear. Any planetary retinue would include only small hard-surfaced rocky-silicate planets like Earth, Moon, Mercury, Venus and Mars - *no* gas giants like Jupiter, Saturn, Uranus, Neptune!
- A star considerably less bright than the Sun, won't ever have burned hot enough to blow clear *any* of the gas left over from its formation. So if it has planets, they'll *all* be gas giants, save for some moons and asteroids.

At least, that's my best bet. But for the sake of argument, what if there is a hard crust silicate planet at a range where it receives about the same light in watts/m2/sec as Earth? What could we say about it?

First, that's pretty close in. Proxima produces only one twelve thousandth as much light as the Sun, and our hypothetical habitable world must orbit only about 840,000 miles out from Proxima's center, let's make that 800,000 from its surface, a dull red disk many times the Sun's apparent diameter in our own skies. 'Proxima Prime' would circle its sun in only 60 hours - its year. At this intimate distance, less than 4 times the Earth-Moon distance, Proxima would exert an incredible tidal force on the hapless world, one more than 600,000 times as great as the Moon's tidal force on Earth. (Tidal force varies with the mass *and* inversely with the CUBE of the distance.) The planet would be quite ellipsoidal with the long axis aimed at and away from the sun, its rotation hard-locked.

If there were an ocean, it would have no tidal ebb and flow but be permanently piled deep on the sun-facing and sun-averted sides, submerging any highland continental areas, and correspondingly shallow (or dry-parted!) at the fixed dawn/dusk lines - this over and above an already egg-shaped crust. Plus its waters would range hot to warm on the nearside and cold to permanently frozen all the way through on the farside. Worse, this might not be a stable situation. Over time, incessant prevailing winds would carry any evaporated water vapor to the night side, adding to the amount of ice permanently cold-trapped there.

If the orbit of our conjectured Proxima Prime was not fairly circular, but say as eccentric as the Moon's or more so, tidal heating of the core from libration effects alone would keep the interior molten, resulting in major sustained volcanic activity through a thin, fracture-laced crust. The gases associated with volcanic eruptions on Earth would quickly have been worked out of the planet's interior, providing a thick atmosphere reeking of sulfur and brimstone. Instead of volcanic plumes and explosions, there would only be repeated gushing of lava, with some basin areas never having time to really cool down. This volcanic heat might help to prevent the eventual cold-trapping of the entire water endowment on the night side.

What if we put our orbit back half again as far, so that the permanently sun-facing portion isn't overheated. That gives us an orbit one and a quarter million miles out, and a 'year' a whole 4.6 Earthdays long. (Horoscopes would still change by the hour, making astrology a prestige profession if Proximians were as incorrigibly gullible as humans.) But even if, given that a higher portion of the radiation budget of such stars lies in the infrared, and that we may want an orbit even further out (lower light levels but with moderate temperatures) the situation does not change materially.

While there are probably no major hard-crusted planets around M stars at any distance, there could be sizable moons. But at suitable light/heat range, a moon would have to be impossibly close to even a Jupiter sized planet for the Jovian's tidal influence to prevail.

Okay, you are game and determined to establish a human/Gaia foothold here, despite these hardiness-evoking conditions come hell or high water. Well, hell *will* come, and any seas may at least boil now and then, for when stars this small have flares, they are of the big granddaddy kind. Proxima doubles, even triples in brightness *and heat* output for a few nightmare minutes on an erratic schedule. Possible warning signals, and probable flare seasons would lessen risk at other times.

We might be smart and choose to live along the dusk and dawn lines in the libration zone (might be the only dry zone anyway). Thus we'd minimize our risks and, occasionally, be able to see the stars. Yet, besides providing emergency sun-facing shelter for ourselves, we'd have to arrange some sort of fast automatically-deployed shelter for all our exposed crops (planted on sun-facing slopes) if we didn't want them prematurely rad-fried, rad-baked, or rad-broiled *on the stalk*.

Human beings - and, via genetic re-engineering, our plants with us - are extremely adaptable (adapting to the red-centered spectrum of such stars is a must). If there is such an unlikely world in this or any other red dwarf M-star system, it would take a special breed of people to accept the challenge, and an ever rarer breed to meet it effectively so as to survive long term.

Any strain of humanity (or of any other techno-sapient race) that managed to eke out so much as a stalemate on such a hostile host world, *and* go on to repeat the feat in one M-star system after another, would soon *permanently dominate* the galaxy. For seven out of ten stars fall in this class. What is more, M-stars burn their nuclear fuel at a miserly pace, and have stable lifetimes up to ten times or more as long as do solar G-type star-suns like our own.

To be sure, some M-stars are less challenging. Lalande 21185 is a relatively more massive M2 type star 8.1 light years away with fully 1/160th the Sun's intrinsic luminosity, so that its geophote range lies 7 plus million miles out, giving a year of 3 plus weeks, subject to a shaping tidal force 'only' a thousand times as strong as the Moon's distortion power on Earth.

If there are any 'havens' around M stars, and *if* despite the growing sissification of our breed, there are a standout handful who want to head out that way (the "M-wave" or the "Emmers"), I'll cheer them on from my grave, happy to have turned back into star-dust before being presented with the chance to join up.

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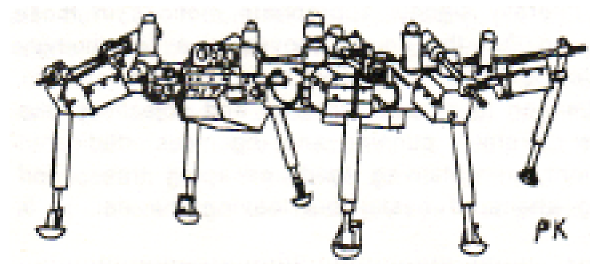


"Atilla", a 2nd generation buglike robot

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

ROBO-ANTS

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

By Peter Kokh

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

At Massachusetts Institute of Technology, MIT, researchers pursuing robotic artificial intelligence have abandoned the conventional forbiddingly centralized, computer- and software-heavy, "top-down" approach to artificial intelligence patterned after the human nervous system and various problematic theories of how we perceive, think, and decide. Instead, led by Australian-born Rodney Brooks, they are taking their cues and clues from the very different architecture of insect intelligence. Insects are highly successful at tackling complex feats on a routine basis despite their minimalist nervous systems and tiny brains. This is because, in bottom-up fashion, they operate by pyramiding more complex behaviors on simpler ones starting with simplest autonomous reflexes in individual legs and sense receptors. At each stage, there is no more coordination from above than there has to be to achieve a certain purpose such as walking or climbing or burrowing; and the animal's brain is called into play only when stimuli and the need for appropriate reaction spill over certain threshold levels. By terracing simple steps, activities that would otherwise seem dauntingly complex, are easily handled.

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

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

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

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

(1) Another Model of Bottom-up Intelligence:

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

This curious creature carries some unfortunate and factitious evolutionary baggage that has kept it trapped at a level far below what its 'alien' architecture should have allowed. To give just two 'for instances', it has green copper-based blood (hemocyanin has only 1/20th the oxygen carrying capacity of iron-based hemoglobin, limiting its endurance), and the female lays swarms of minute eggs, wherefore, lest it eat its own young while they are too small for it to relate to, the female has been naturally selected to die shortly after the eggs are laid. Despite such handicaps, the octopus is far more capable of intelligently "manipulating" its natural benthic world than the more pelagic dolphin, the usual darling of popular esteem (the sea bottom being a more structured and intelligence-challenging setting than the open sea). In some still future time, it may be possible to correct some of the octopus's evolutionary missteps by genetic engineering (perhaps splicing in bits of genetic material from other mollusks with more desirable traits), and thereby set an altered cephalopod strain back on an upwards course with destiny (sophopods, the wisefeet?). But that's the subject for a Sci-Fi novel -- someday.

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

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

(2) Refining Sensory Apparatus:

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

Sight might be offered not only in a front-top-center stereo scanner on a stalk, but perhaps in a task-appropriate 'eyespot' on each foot, or forefoot, with the information not being called to the attention of the central processor and thus merit the gaze of the stereo-scanner, unless its content calls for organized response.

In the octopus, the two eyes can cooperate or work separately when the situation allows divided attention. We tend to think two eyes are needed for range-finding (depth-perception) but one bobbing eye does just as well. We are currently at a juvenile level of playful fascination with a digital feast of irrelevant data completely overwhelming efforts at analysis.

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

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

(3) Co-operative Robo-Ants:

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

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

We'd first build a Scout class, that explores, reconnoiters, classifies and marks the terrain it moves over. This is what researchers are aiming at now. Sargents could direct deployment, ensuring full coverage of a work area and act like sheepdogs, keeping units from straying. We can also have Harvesters whose job it is collect objects of interest noticed and tagged by the scouts or perhaps already placed in convenient 'hay bale' piles for later collection. Refuellers or Rechargers could be on the lookout for stalled ants with an activated out-of-fuel or low-charge blinker. Retrievers could pick up disabled scouts and return them to the main staging area. Mechanics could affect simple repairs of disabled units, refresh their programming, or cannibalize them for parts. Stragglers from other robo-insect collectives could be adopted and reprogrammed. Inspectors could accept or reject (undo?) work not up to their built-in standards. Finally, there could be a queen or mother unit possibly atop a mobile hive-shelter to which individual ants could return at nightfall to conserve heat, to be recharged, to receive updated instructions etc. The mother unit need only recognize progress towards the realization of the collective mission, that is, able to send out a deactivation signal when the job seemed finished, spur on lagging castes, etc.

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

(4) Complex Missions for Robo-Ant Collectives:

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

Site preparation and pre-deployment tasks:

- Remove boulders from an area, grading and raking, for roads, skidways for craft landing horizontally, and pads for spacecraft landing on their retros.
- Excavate spaces for habitat modules, fuel tanks, etc.
- Collect regolith, load conveyors, and relay it as a shielding blanket over pre-deployed habitats etc.
- Identify desirable mineral and rock samples and pile them up for convenient later retrieval.
- Do pre-mining sortation, depositing richer concentrations of sought-after elements as 'leavings'.
- Sinter or gravelize 'porch' areas and approaches to minimize dust transport into habitat interiors.
- Set out tritium marker lights for roads, landing pads, and in lava tubes and other permashade areas etc.
- "Primage" lunar regolith for use as agricultural soil, sifting out ultra fine particles, and transforming glass spherules into zeolites to promote mineral ionization.
- Spin web mesh receiver antennas over suitably sized

craters for radio astronomy and satellite solar power

- Survey/map lava tube complexes on the Moon/Mars.
- Harvest thin patchy water-ice deposits in lunar polar permashade not otherwise economically recoverable.
- Replace damaged panels in extensive solar arrays.
- Plug outguessing pores on comets in preparation for their shepherding to the Earth-Moon vicinity.
- Locate and map fissure escape routes for episodes of outgassing on the Moon that we notice as 'TLP' glows (Transient Lunar Phenomena) and mark those where the volume of flow may provide an economic resource

Within habitat-biosphere areas:

- Tend farms, trimming dead leaves and stems,.tilling, spot-watering, spot-fertilizing, detecting early signs of infestation, picking ripe produce, etc.
- Sort consumer and industrial recyclables
- Clean streets and other pressurized passageways
- Change failed or failing light bulbs and tubes
- Detect and repair minor slow air and water leaks
- In service of a future Mars terraforming effort:
- Locate and pre-tap areas where water-ice perma-frost rises closest to the surface.
- Physically, and even chemically (where possible with non-consumed catalysts), condition raw soils, sands, and gravels for the introduction of microbial cultures
- Channelize potential canalways (identified by orbital altimetry mapping) from polar to equatorial areas; and channelize the 'saddles' between neighboring unlinked basins to accelerate development of a mature drainage system in expectation of future rains.
- Out Among the Asteroids and Comets
- Locate, map and presort and/or pretreat surface-available mineral resources
- Pre-mine desired resources on small astrobergs so that only resource-poor tailings need be used as mass driver pellets in coaxing it into a handier orbit
- Locate intact remnants of impacting bodies
- Look for 'parent-body' tell-tale signatures
- Excavate pressurizable galleries for outposts
- Produce fuels from otherwise unpromising fields of volatile-rich materials
- Make and cache 'bricks' and other simple building materials in advance of crew arrival
- Locate outgasing pores or vents on comets during their dormant phase
- Tunnel to the core of comets, analyzing the material all along the route

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

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

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

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

[Star*Bound] *series continued*

CIRCLING SOME YELLOW-WHITE "F" SPECTRUM STARS MAY BE AN OVERLOOKED SCATTERING OF

WELCOME-MAT WORLDS

By Peter Kokh

The conventional wisdom about where we ought to look for indications of technological civilizations like our own and/or where we might find suitable new "Earth-like worlds" on which to sew the human seed has always been "circling stars like the Sun" in color and temperature: warm yellow G-spectrum stars - and perhaps also around those just a bit cooler and oranger: K- spectrum stars. This has been the prevalent view for many decades.

First there was the discovery that single unpaired stars that rotate slowly (as does the Sun, in about 28 days) are likely to be attended by a retinue of planets. Now every survey shows that in general, only G-, K-, and the even cooler, redder, and smaller M-spectrum stars are slow rotators. Some slightly hotter stars of a yellow-white or F-spectrum may also be slow rotators. The balance of hotter, whiter and bluer stars seem to rotate swiftly, in a matter of hours. The significance of this is that if the Sun could somehow draw in all its family of planets, as a spinning skater does his or her arms, its rotation would speed up to a mere two hours! In other words, by far the greater portion of the Solar System's angular momentum is invested in the orbital motions of the planets, not in the much more massive body of the Sun itself.

The conclusion that seemed universally drawn, never to be questioned, was that the hot)-, A-, and F-spectrum stars were lonely giants. In their ranks are most of the stars you see at night like Vega and Sirius (along with so-called G-, K-, and M- giants like Capella, Arcturus, and Betelgeuse either at the brilliant start or end of their nuclear burning stages). Stars likely to be planet-laden are smaller and fainter, visible to the naked eye only from nearby, a few light years at best.

I found it strangely disconcerting after the recent discovery of proto-planetary dusty disks of matter around Beta Pictoris, Vega, and most recently Fomalhaut, each too hot to fit the schema, that there were no public admissions by astronomers that the earlier comfortable expectation was wrong, and why. To me it seems the "skater-hypothesis", for want of a better word, was incomplete to begin with. In our own system, 98% of all the angular momentum invested in the planets is contributed by the "gas giants", 75% of that by Jupiter alone. Now hotter stars in their youth may easily have blown most of the hydrogen, helium, and other gasses *out of* their planet-forming regions altogether, so that *only* much less massive solid surface rocky silicate planets like Mercury, Venus, Tellus-Luna (Earth/Moon), and Mars could form. In such cases, the central sun would retain most of its rotational speed.

With this correction to the original insight, we might expect the planetary systems of hotter stars to be devoid of gas giants, and those of much cooler stars to include gas giant planets exclusively. In other words, in seeming poetic justice, the smaller the star, the more massive its total complement of of planets, and vice versa. The Sun, being in the mid-range, has some of both type of planets and just where you'd expect them to be. I have yet to hear anyone make that point.

But there is one other extremely important consideration. Hotter, more massive stars burn more intensely and exhaust their nuclear fuel much more quickly than do cooler, less massive ones. Some hot stars are veritable flash-in-the pans, their brief but spectacular lifetimes over in only a few million years. Our own star, the Sun, has burned fairly steadily for some 4.6 billion years already, and will probably enjoy a stable period of similar length down the road, before the drastic changes of stellar senescence overtake it. At the other end, the coolest red stars shine with a steady slow-burning light for a hundred billion years or more.

Now our galaxy, the Milky Way (the only name we've ever given it), is probably 15 billion years old, give or take a few. ALL those stars still burning since the original episode of star formation are small, faint, cool red M-stars. The vast majority of stars you can see at night are hotter and more massive and can only have come into existence in relatively recent times, perhaps after animal and plant life had already colonized Earth's continents. The average age of more sunlike G-stars must statistically be close to the Sun's age, since it is in midlife.

Perhaps you're on the ball and have already put 2 and 2 together. Stars brighter and more massive than the Sun *by a certain threshold amount* MUST reach the END of their stable life-times BEFORE life (assuming it to be naturally arisen and evolving at a catastrophe-punctuated pace similar to that on Earth, the only example we have to study) can REACH the stage of "reproductive readiness" now attained by Gaia (the name of Earth life as an interconnected whole). So while contrary to former expectations, hotter stars CAN have planets, any life that arises on those favorably placed, WILL BE nipped in the bud by the death of their sun before that life gets to the stage we see here. Again, that is assuming that the pace of asteroidal impact-caused break-outs of evolutionary ruts that has occurred here, is representative. Yes, that's a big "if" - but not an implausible one.

Now we are ready to take the discussion to the next level. If and when we reach the stage of technological achievement that WILL support the sending of interstellar settlement expeditions, arks (not necessarily slow) of people, plants and animals (at least in gene-bank form), then what target-types should we head for? The unanimous suggestion of would-be planet-steaders is to head for "Sun-like" G-star systems. Those who would build their own worldlets of proto-planetary debris, in the "space-colony fashion, have much more of a choice, of course.

Now for the fly in the ointment. This writer maintains that any truly "Earth-like" planet around a Sun-like star will already have its own indigenous living ecosystem. *Whether* it has produced some higher intell-ligence *or not*, we will have **a moral duty to leave such biomes to their own natural evolution**. In other words, if any suggested world is truly "Earth-like", we *ought* to consider it off-limits. Many will violently disagree, not because they question the moral principle invoked here, but because applying it would seem to deny them their entire list of "good" targets. They will be frantic, searching for reasons to put this moral "directive" aside.

There are three outs: The first two will have already occurred to many: **1)** we go to systems with "Sun-like" stars but without truly "Earth-like" planets and "**terraform**" or render "Earth-like" those planets that just missed being so by dint of being a little too near or a little too far from their suns. Or **2)** we *do* go to those systems with native life to settle not these planets themselves, but, in space colonies, all the space nearby, vantage points from which to **study and observe** them without interference.

Yet for the planet-drawn, there is a third out, one which seems *much* more interesting and intriguing! The moral principle we've stated above, *will not apply,* even to the most Eden-like of worlds, IF it circles a sun that *must die before* native life has any chance to blossom and quicken with spirit. Now mid-range F-spectrum stars, say F3-F8, are in this range of life-expectancy.

They can expect 2+ to 4- billion years on the stellar mainstream, burning steadily enough to nourish life on properly placed planets.

My thesis is that *these* F-stars, *not those* on the usual G-star list like Tau Ceti or Epsilon Eridani, are **the ones that should be setting our settlement juices flowing.** If ethics are as universal as every philosopher holds, the same conclusion should "occur" to other intelligent species.

Now the hotter a star type, the fewer there are of that kind, and conversely, the cooler the more. Thus, despite first appearances, the attention-getting signpost hot stars that dominate skies everywhere are much rarer than the cool faint stars that swarm below the threshold of naked-eye visibility. Approximately 4% of the stellar population is of the Sun-like G-spectrum type. The somewhat hotter yellow-white F-stars form a smaller sampling, perhaps 2%. But if that's where the union of ethics and opportunity leads, that's where we should look to expand.

Procyon is easily the best known star of this type, at least to those of us in northern latitudes, and we might refer to such stars as **Procyonids**. But it is not itself a candidate, being part of a double star system. Its companion is a white dwarf, a hot but very tiny corpse of a once much brighter star, even brighter than the Procyon we see, that has already come to the end of its mainstream life. Procyon A must sooner of later follow its companion into oblivion.

But there are other stars visible to the naked eye which fall into our narrowed classification. As luck would have it, there are more of these visible in the southern skies than this far north. Among those apparently single stars (less than half) closer than 20 parsecs (65 Lt Yrs) with names or Greek letter or Flamsteed number designations, some of the following may be worthwhile:

- Candidate stars are listed in rising order of right ascension or celestial longitude.
- Those with the lower F#s have the shorter lifetimes; so those with the higher numbers like F7 and F8 are more promising bets.
- The more the light years distant, the less certain the distance estimate. Those within 10 parsecs (32.58 LY) are shown in boldface.

□ Beta Cassiopeiae	F2	50 light years
□ 6 Ceti	F6	53 LY
□ 19 Ceti	F8	51 LY
□ 44 Andromedae	F8	65 LY
□ Nu Phoenecis	F8	45 LY
□ 50 Upsilon Andromedae	F8	52 LY
□ Gamma Doradi	F0	55 LY
□ Zeta Doradi	F8	43 LY
□ 111 Tauri	F8	52 LY
□ Eta Lepi	F0	49 LY
□ Beta Carinae	F5	58 LY
□ **Beta Virginis**	**F8**	**32 LY**
□ Alpha Corvi	F2	49 LY
□ Sigma Bootes	F2	57 LY
□ Alpha Prime Librae* (* distant companion of Spica)	F5	57 LY
□ 45 Bootes	F5	65 LY
□ Beta Trianguli Australis	F2	39 LY
□ 58 Ophiuchi	F5	57 LY
□ Zeta Serpentis	F3	65 LY
□ **Chi Draconis**	**F7**	**25 LY**
□ Psi Capricornis	F5	39 LY
□ **Gamma Pavonis**	**F8**	**28 LY**
□ Tau Psalterii	F5	60 LY

That's admittedly slim pickings. Of the prize contenders, Beta Virginis and Chi (pronounced Key) Draconis are visible to northern observers. Of these stars, perhaps some percentage have planets on which life has appeared, doomed to be tragically nipped in the bud before it can possibly reach full flower. **Such worlds**, since they cannot see maturity of life on their own, but only through "outside" intervention and acceleration, **can attain deserving fulfillment only through settlement by intelligent species arising elsewhere.**

Now some of these suns will be too young, any favorably placed planets not yet settled-down geologically, on which life has either not begun or is only in the tentative stages. Ideal for us are worlds 2-3.5 billion years old with at least a few hundred million years of useful time left on their ticking-bomb suns. Yes, so what if after a few hundred million years we'd have to move? No one in Canada or Scandinavia seems too very bothered by the near certainty that their homelands will be wiped slate-clean by the next episode of advancing glaciers due within a mere 10-50 thousand years! While some few neurotically insecure types are already worried by the impending death of the Universe some hundreds of billions of years in the future (and speculate how we might cheat this common fate), for the overwhelming majority of us, the promise of some hundreds of millions of years around which to plan our lives and civilizations is quite generous enough.

By heading for the somewhat fewer and further "fated-yet-friendly" worlds around yellow-white F-suns, we'll find destiny enough, *with* an uncompromised conscience. What will be in store for those who take up the challenge to settle these unfinished raw worlds that would otherwise be condemned to remain such? We might take a look at the Earth of 1/2 to some 3 billion years ago. But that's a picture we can only see through the fog of time and not yet uncovered evidence. As best we know at this time, the first primitive life appeared on Earth when the planet was about a billion years old, or at least we've not yet unearthed indications of its presence much before that.

Early life was predominantly cyanobacteria, previously called blue-green algae. This very primitive life form dominated the planet for two billion years or more, and was largely responsible for sweetening the atmosphere by replacing carbon dioxide with oxygen.

The common view has been that the continents themselves were barren until about 500 million years ago, life being principally an oceanic phenomenon before that. But in Science News for December 9, 1989 an article entitled "Supersoil" tells of newly found indications that cyanobacteria had invaded the continents possibly a good billion years earlier. They apparently performed invaluable yeoman work by creating stable soils, greatly increasing the accumulative effects of weathering by contributing erosion resistance, and even reduced land temperatures substantially (soil being cooler than bare rock). These hearty microbes can withstand long periods of drought in a state of suspended animation, yet burst into frenzied activity within seconds of it starting to rain.

According to this reconstruction developed by Tyler Volk, New York Unive. and David Schwartzman of Howard University, Washington DC, (upon investigation of modern cyanobacteria-rich soils in Utah), the humble service performed by these cyanobacteria slowly prepared the continents to receive the first true primitive land plants much later on, which paved the way for the first amphibians, and so on.

While we might find some F-sun worlds further developed, with Cambrian type life in the seas and on the land, most such worlds we come across should be somewhere in the much longer cyanobacteria-dominated stage. If this life is of the dextro- or right-handed persuasion, as is *all* life on Earth, higher life forms tracing their ancestry back to Earth should transplant well (not without casualties), both in the seas and on the land. But if the indigenous life is built on left-handed molecules (stereoscopic twin molecules and organisms built of them, will have identical properties and characterristics but find each other mutually indigestible), we'd be hard put to establish food chains we could use to support our existence. We do not know at this time if so-called right-handed life is a 50-50 possibility, or if by chance it has become widespread throughout the galaxy by some sort of preemptive (but not necessarily purposeful) "seeding" as in the "panspermia" hypothesis.

At any rate, planets pre-readied by cyanobacteria would seem a lot more attractive than totally barren worlds that would have to be terraformed from scratch. At least our yellow-white F-sun worlds will already have rich fertile soil and teeming seas and quite likely oxygen-sweet air, plus a future that belongs to us by default.

"On to Chi Draconis!" You read it first in **MMM**!

LOCO *MOTION*

Mobility in Very Low Gravity Environments

– *REGOLITH TRACTORS* –

by Michael Thomas, Seattle L5 Society

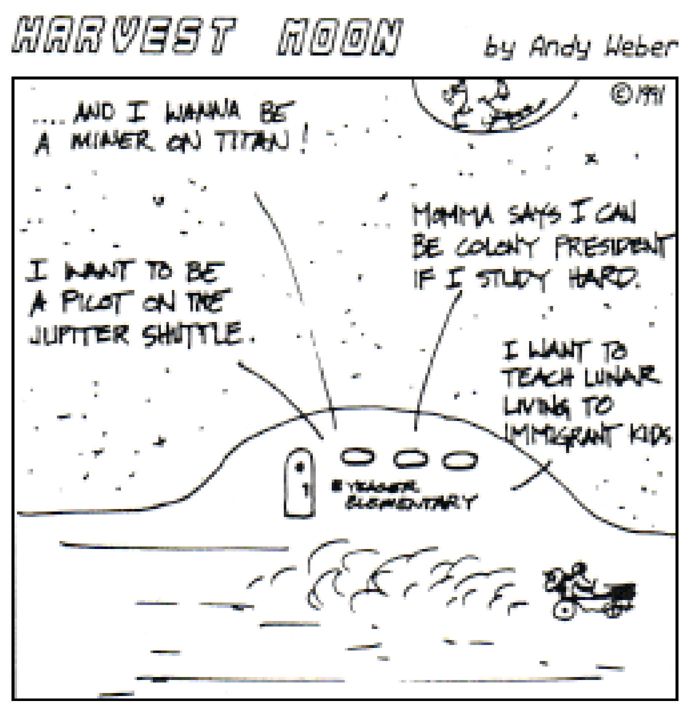
In the February issue (MMM #42) I suggested that simple hand tools would be useful in getting around on asteroids. Here, I will suggest some power tools for the same purpose. (Again the tools must develop enough traction to pull one forward along the surface, while at the same time holding one down.)

An individual tractor might consist of something like a rototiller, but with a small plowshare behind the rotors that would dig in and help to hold the thing down as it moves along. Atop this assembly there would be a long handle with handlebars and motorcycle-like controls. This could be equipped with sample collection bags, etc. and serve as the "Manned Maneuvering Unit" of the astroprospector set.

This same concept can lend itself easily to the development of larger vehicles. The "asteroid buggy" would have a bladed rotor for each wheel, with a plowshare beneath each axle to hold the axle down, and/or behind each individual wheel, to hold the wheel down. If necessary to further reduce bouncing in the very low gravity (VLG) environment, canisters could be mounted on the frame of the vehicle and filled with regolith to increase the mass of the vehicle. This would not significantly add to the traction of the vehicle in VLG, but it would increase it's inertia so that it would take a larger bump to change its direction significantly.

Another tractor concept is for a tank-treaded vehicle with some kind of hooks of blades on each cleat that will dig into the regolith and hold the vehicle down while moving it forward. This tractor might also need one or more plowshare sto hold it down.

The exact design of the rotors and plowshares would depend critically on the density and texture of the regolith. A truly all-purpose tractor might have to have changeable blades for dense regolith and wide blades for loose regolith. **<MT>**



MMM #46 - JUN 1991

"FOOTLOOSE" AMONG THE ASTEROIDS

By Peter Kokh

The vision of a hardy population of prospectors, miners, entrepreneurs, traders, gypsies, pirates, hookers, and get-away-from-it-all pioneers-in-general slowly humanizing the Asteroid Belt has long been an established theme in Science Fiction and, toned down *a bit* in expectations, in the earnest forecasts of space development proponents. The challenges are more sobering than most imagine or would care to admit. In MMM #35 MAY '90 "Ports of Pardon", "Feudalism" , and "Tea & Sugar" pp3-6 [MMM Classics #3] we tried to bring a sense of realism to the discussion by illustrating how dauntingly vast and sparsely-islanded the Asteroid Belt really is, and how pioneers might cope in such an ultimate boondocks. These articles deal more with sociological and political considerations.

A more immediate challenge is how asteroid trailblazers and the pioneers who follow them will cope with very-low gravity, not just for a mission, but long term - lifelong, generation after generation. Some writers have passed this off rather casually, predicting that *homo zero-G* will develop into a stable subspecies with its own selected/bioengineered/inherited physiological adjustments. Perhaps. But the first asteroid-busters will be humans as we know them, humans like you and me. And it is *this* vicarious expectation which grabs our interest.

The problem is real. The 'highest' gravity level we will come across our there is a scant 3% Earth-normal (1/6th lunar-normal) on Ceres, by far the largest and most massive of the minor planets [diameter 1003 km or 616 mi with a surface area equal to the continental U.S. west of the Mississippi]. But Ceres is quite atypical. In fact, while major repair, service, trade, and manufacturing nodes in the Belt may be located on the likes of Ceres, Vesta, and a handful of other relatively large asteroids, it is at least reasonable to suppose that most resource exploitation will involve smaller bodies, perhaps much smaller ones even than Phobos and Deimos or Gaspra.

OUT-VAC (Out on the surface, in vacuum):

Setting aside for now the question of how settlers on the larger worldlets will adapt physiologically to life at very-low gravity (or whether such *permanent* adaptation is even possible), let's consider how prospector-miners will be able to negotiate their surroundings - where the gravity is so negligible that anyone with still-good muscle tone will be able to launch h--self into space with a simple jump, or by a momentarily stuck backpack thruster, or even by an over-energetic twist of an old-fashioned wrench on a stubborn nut or pipe! (Special torque-free tools have already been developed for shuttle astronauts and MIR cosmonauts; so this in theory is no problem; but what *if* the needed tool is broken and one *must* make do with a gizmo that does *not* compensate for torque?)

Even on asteroids as large as Ceres, it may be impossible to "walk" by some exaggerated caricature of the now-famous lunar shuffle or kangaroo hop. Traction will be effectively zero. How will one be able to move from one work spot on the surface to another, *efficiently* (sans exhausting waste motions) and *safely*?

MMM Assistant Editor Mike Thomas (Seattle L5) has written a couple of interesting pieces lately that serve as an introduction. in "LOCO*MOTION* - Mobility in Very Low Gravity Environments" [cf. MMM #42 FEB '91 pp12-3] Mike describes some mobility aids prospector-miners can use. Cables anchored to the ground at intervals by harpoons driven into the surface as the cable is paid out from a hovering spacecraft, would serve as an attachment guide for slip-ring tethers [why not electric trolley grippers?] along routinely traveled corridors. For getting around "off the tethered track", Mike describes a pair of "claw-walkers" which would alternately dig in and close and open and pull out of the loose surface 'lith.

The leverage provided by the engaged claw walker would assist in pulling out the mate, advancing it, and driving it into the soil a distance ahead. If one wanted to cover a greater distance more rapidly, telescoping handles on the claw walkers would allow one to 'stilt' along above the surface in a more open 'stride'. [A pair of tethered bazooka (recoilless) fired harpoons with remotely closed and opened anchor heads might function similarly for more rapid negotiation of even greater distances.] Such tools depend on the compactness of the soil about which we can now make only intelligent guesses based on lunar experience and an analysis of forces working on asteroids to compact vs. to fluff up the soil. Hoe like tools could be used where the soil is less dense, and as drag-brakes. Magnet-tipped stilts might work on iron rich asteroids. But then, so might magnetic boots.

In MMM #45 MAY '91 pp12-3 Mike describes VLG (very low grav) Regolith Tractors with rototiller like wheels and plowshare like ground-hugging assistance. The vehicle could be ballasted with local regolith to increase its mass and act as a motion stabilizer - an elegant suggestion!

Much of the problem of VLG surface motion disappears if indeed the motion is "smoothed out". Walking is a very jerky staccato motion which works where gravity overwhelms. But even where gravity is minimal, *provided* motion can be smoothed out sufficiently, surface vehicles *should* work. This might require very sensitive active suspensions, touchy and gentle both, heavy ballasting as Mike suggests, and a speed deliberate enough to allow these systems to work. [Computer simulation called for. Attention buffs!]

For personal mobility, an open frame spherical Squirrel Cage with the operator harnessed to a *heavily*-ballasted platform suspended within from the axle (i.e. below the center of gravity) might provide both smoothness and traction. While the gross unevenness of small-world terrain might suggest a problem negotiating inclines, both upwards and downwards, one should bear in mind that in VLG these topographic features are *effectively very flat*. Vehicles generally of this design could be developed for profit as competition to dune buggies here on Earth, with races, rallies, annual competitions etc. ***[Entrepreneur Alert!]***

INDOORS, MIDDOORS:

The challenge to personal locomotion will not be limited to situations on the exposed asteroid surface. Even in the pressurized safety of habitat interiors (construction shack *or* full-blown settlement) 'on' or 'in' such miniworlds, getting about may be accomplished by means more reminiscent of Skylab and MIR than of any everyday gravid experience. Stairs and ladders, ramps too, will be useless. Hallways of conventional architecture would likewise serve poorly. Instead, passageways, whether horizontal, vertical, or sloped, might better be designed as tubes with suitably spaced hand holds, or better, handrails running their length. A pair of bidirectional *moving* cables in a recess in the wall/ceiling could serve as something to grab on to (by hand or by hand-held grappling device) thus allowing one to hitch a ride and "trolley along". If the day comes when there are belter settlements large enough to require transit systems, such a simple Personal Trolley System based on "hitching cables" might take care of 'traffic' needs quite well.

To be sure, there *will* be and up and down in very low gravity environments - not of the let's-pretend variety (for the sake of orientation and convenience) as aboard the planned space station, but in a real sense. For even very low gravity is sufficient to keep things in place on a floor or shelf. But such placement will be touchy as the slightest movement or vibration could set items in motion or toppling.

Maritime experience will point the way with the many convenient stay-put aids now in use for bobbing boats. Velcro pads and spots ("a place for everything and everything in its place" will become an entrenched way of life, not mere good advice). Item-specific countersunk holes, pegs, and grappling hooks will also be helpful to reinforce the feeble place-keeping effects of the local semblance gravity. Sub-maritime underwater (but in -water rather than in submarines or seafloor habitats) simulations here on Earth could help ferret out the practical problems we need to address in preparation for very-low gravity life.

While things will fall, they will do so with dreamlike slowness, to be watched, not glimpsed. And within habitat situations, this might seem at first blush to warrant a lessened concern with fragility. However, items will need to be resilient all the same, for the real danger will be from crashing into things. Like the drunk who cannot confine his path of motion to item-free pathways, mini-grav pioneers will be a threat to anything fragile. For the less the gravity, the less the traction, the less the ability to self-brake, slow down, turn, or maneuver in any way.

This suggests that rooms will be furnished quite differently. There will be no islands of furniture, potential obstacles and hazards to motion. Furniture and furnishings would best be put in alcoves and small cubbyholes or in railed-off/fenced-off areas to segregate them from even light domestic traffic flow. Alternately, in-room trafficways could be demarcated by motion-confining handrails or railings. Those who have had the experience of having to rearrange their home to accommodate a person who has just lost h-- sight, so as to put things out of harm's way, will appreciate the problem.

LEG OF HUMAN:

A number of science-fiction yarns dealing with life in the Belt have pointed out that the leg-amputees will be at no disadvantage in such environments but may even adjust better. Face it! Of what use will be one's legs? In such low gravity, locomotion by hand or hand-held assists will be more than adequate. Legs may be of some use to the worker who has to brace h--self to "lean into" his work (e.g. using a drill, wrench, screwdriver, etc.) *when* there is something handy to brace against! But beyond that...?

Will legs be a liability, useless appendages requiring food to maintain bulk with no purpose? Might newborns have them amputated as a matter of course, even as the puppies of some dog breeds have their tails bobbed or ears cropped? Repulsive as this may seem to our aesthetic sense, it may become the 'reasonable' thing in the brave new world out among the asteroids.

In truth, hypothetical sapient technologically self-advancing species based on an octopus-like body architecture would seem to be better suited for zero-G and very-low-G life than 'bipeds' like us. ("Octopus", Greek for eight-footed, is really a misnomer. "Octochir" [pronounced octo-keer] for eight-handed, *would* have been a more descriptive term.)

A far better solution is to find new duties for our legs, things they can do to keep the rest of the body free and more productively occupied. After all, we have effectively "reassigned" our hands/arms to duties other than grasping Tarzanian vines and peeling tasty bananas! That still on-going reassignment is a good candidate for Best Actor in the drama of the rise of human civilization and culture.

The idea of leg-duty reassignment was the basis of my earlier short piece on "PODOKINETICS" [Greek: Foot Power Systems] in MMM #25 MAY '89 p.3 [MMM Classics #3] in which we suggested an amendment to the "Protestant Work Ethic" in which those living and working indefinitely in Zero-G or very-low-G environments allow themselves only such electronic and electrically operated conveniences and personal luxuries (TVs, radios, stereos, personal computers, etc. etc.) in which the power was provided not by plug-in or battery-supplied electricity but by foot/pedal-operated generators. This custom could be extended to cover things like power tools, and small kitchen appliances, even the heat of one's shower water, etc. Such things could be developed *now* as a health fad. ***[Entrepreneur Alert!].***

In reality, such "make-work" jobs for legs and feet will make more sense for those who find themselves in low-G situations for only temporarily periods - a simple way to keep fit without setting aside blocks of time for explicit exercise. But as to exercise, where 'middoor' spaciousness permits, specially designed "Belter": sports in which leg-action is *the* dominant feature, might be a wise and popular choice. [Attention, Computer Game Designers and simulators!].

But getting back to the "Brave New World" theme of those "*forsaking* high gravity worlds *forever*, such atrophication-stalling remedies may be pointless. A more straightforward approach would be to replace the legs with a second set of much more versatile arms and hands. Using them would be no problem as instinct follows or flows from body equipment, not some inherited brain-set. This could be done by genetic engineering, producing an inherited feature, or (my preference) by a routine procedure on the early fetus. Such a choice would allow reversion to 'normally' bi-pedal offspring at any time, as a personal family choice, e.g. in anticipation of a permanent return to the terrestrial homeland, or of a child's university education on Earth, or of the opening up of some new high-gravity frontier in the solar system or beyond.

More than any other part of our body, our legs and feet have evolved to negotiate the gravity-structured environment of life on Earth's highly up/down polarized surface. Making sense out of this evolved inherited equipment in environments not so intensely vertically structured will provide a central theme for adjustment to life out there. As we move out of our traditional eco-range we will have to take ever less and less for granted. ‹‹‹ MMM ›››

[Star*Bound] *series continued*

NAME GAMES FOR PLANETS AROUND OTHER SUNS

By Peter Kokh

In the June 1990 issue of Astronomy, Deborah Byrd, the creator of the "Star Date" radio program, expresses her unease at the very real near term prospect that we will soon (at long last!) be discovering one new planet after the other - *around other stars* -and feel ourselves compelled to give names to these exo-worlds. Names *are* how we prefer to handle things. We can use grid and/or cataloging numbers, of course. And for many objects literally too numerous to name, this is the only designation we ever give them.

Traditionally, the "right of naming" belongs to the discoverer. Some delight in this ritual sharing in "Adam's privilege"; some do not, and gladly leave the job to others. Our naming talents rely generally on naming the new after the familiar. Only seldom do we invent new names from scratch. It is easier, too, to follow precedents and soon practice becomes tradition. Most lunar seas (maria) are named after states of mind or weather, lunar craters after past astronomers. On Venus, we are naming the large features after mythical women, the small craters revealed by *Magellan*'s imaging radar, after historic women.

The exceptions grate - like two lunar seas named after persons (Humboldt and Smyth) and one for a city (Moscow). And there are unfortunate cases of missed opportunity. The asteroids discovered to be orbiting in formation with Jupiter in the L4 and L5 Lagrangian points, 60o preceding and trailing Jupiter in its orbit about the Sun, have been named after heroes from Homer's tale of the Trojan Wars. But the chance to reserve L4 objects for the Greek heroes (the first discovered was designated #588 Achilles) and L5 for the Trojan heroes, was lost forever through the sloppy lack of forethought by one person.

A problem arises when the existing pool of names nears exhaustion. The asteroids were at first given names taken from Greek and Roman mythology - we had no idea how many we were about to discover! - until these began to run out. Now we find such whimsical names as "#1625 The Norc" (named after a computer), Most traditional name-pool sources have been already severely drained by the big flood of surface features revealed by space probes from *Luna 3* 's historic first photos of the Moon's previously unseen farside hemisphere in 1959, to *Voyager II* 's recent grand finale at Neptune/Triton.

Nowadays, the IAU, International Astronomical Union, has a committee to oversee the naming backlog and guarantee that there is a semblance of pattern and appropriateness. But even so, we have had to dip into much more recent mythology to name the newly found moons of Uranus, with characters from Shakespeare's "Midsummer Night's Dream".

So what will we do if we discover exo-planets in great numbers? [MMM # 36 JUN '90 "Exo-Planets" p. 9 [MMM Classics #4]; and "Barnard's Star" this issue, below] I think this time **we ought to prepare for the flood with some helpful ground rules**. First, please note that only a few of the very brightest stars visible from Earth (and the Solar System) have names - those being given by early Arab astronomers. Vega, Deneb, Altair, Capella, Sirius, Rigel, Canopus, Alcor and Mizar, Betelgeuse - all these beautiful, venerable names are phonetic corruptions of millenium-old Arabic namings. A few more stars have 'name-like' Bayer designations, combinations of Greek letters and a constellation name: Alpha Centauri, Tau Ceti, and Sigma Draconis, to name just three favorites of Science- Fiction. Next in line of name-like handleability are those with Flamsteed numbers like 66 Orionis, and special catalog numbers such as Wolf 359 and Groombridge 34. But then we are left with the vast majority which at best have such unpoetic anti-mnemonic handles such as AC+41o19-173 (which *does* speak to the initiated!).

Now it would seem silly to name a planet that circles a still nameless star!

RULE 1. Only exo-planets around named stars (and those with Bayer letters or Flamsteed numbers etc.) **shall have names.** Planets found around stars with catalog designations only, and all exo-planets at first, can be referred to using small Roman letters, in the pattern of **starname/I.D>#-a**, in the order of discovery within the system. As it is highly improbable that the first planet discovered within a system (likely the local equivalent of Jupiter) will conveniently also be the nearest its sun, a number designation would be premature. (Spica-a may turn out to be Spica VII)!

Remembering which new planets belong to which old stars may be a welcome bit easier for all if the following pro-mnemonic device is employed.

RULE 2. The first planet to be discovered around a named star will be given a name starting with the first letter of that star's name and so on. Thus in order of discovery, the planets around Rigel would be named R----, I---, G-----, E---, and L---, then R-- again etc.

To avoid hesitation, deliberate levities that will all too soon cease forever to be amusing, or ideological mischief, the choice could be left up to ***a computer program*** operating within the guidelines above, which ***would pick names from a two-tiered hat***. Into the first tier could go ***names of make-believe planets from science-fiction*** literature and films published or released before a certain cut-off date such as the date of the discovery of the first exo-planet (imminent). Some of these S-F names would be very familiar: Pern, Arrakis, Trantor, Tatooine, Vulcan. Others would be less well-known. Names of any fictional planets mentioned only in passing (mere name-droppings, not really part of the story) might be excluded, however. Collecting all these treasures would require a labor of love by a team of science-fiction fans. Such a project *has* sufficient appeal to be realized.

The hat's second tier could hold ***a pool of computer-generated random names*** that follow set rules of phonetic composition and spelling to be decided by a committee, filtered to remove those with chance objectionable connotations (e.g. Shat, Shet, Shot, Shut would pass but the i-variant might not). If names from 1-4 syllables are allowed, this pool should supply many thousands of choices. Beyond that, our compulsive naming appetite might be sated, and no one would care.

It is unlikely that we'll also tele-discover moons around any of these planets, or any surface features, until and unless we receive return data from actual interstellar probes, such as the *Star Wisp* suggested by Dr. Robert Forward. [cf. MMM #2 FEB '87, CLIPS p4 - available by SASE plus 25¢]. So for the foreseeable future, we needn't worry about naming such system-local details. Maybe they're better left to future interstellar pioneers themselves - if ever!

And for planet-laden, previously unnamed stars?

But back to the hordes of nameless stars! We might well consider giving names to at least some of those around whom we detect planets, in due recognition of that paternity, if you will. This can be done quite simply by the use of **a formula that gives phonetic alphabetic value to the components of a current numeric catalog designation**. For example, a, e, i, o, u, ai, au, eu, oi, ui could render 1 through Ø. Consonants could be chosen from alternating groups of ten: b, ch,, d, f, g, h, j, k, l, m and n, p, r, s, sh, t, th, v, z, zh.

Given the example above, AC+41o19-173, ignoring the AC and using a 2-part form to reflect the celestial latitude/longitude information, and using the first consonant group for northern stars (+), the second for southern stars (-), we get **Fa-Buinaud** - suitably alien, suitably romantic, and above all suitably back-translatable to the original location-cuing catalog designation. Ignoring the catalog prefix DM, DM-53o117 becomes **Ri-Bath**. **Te-Ditha** translates -62o3371, **Mau-Lusi** +07o9533, etc. Catch the flavor?

Colorless number designations may be fine for stay-at-home astronomers with a wanderlust quotient somewhere near zero. But ***for those of us headed one-way outbound,*** something more Adamic would be a definite psychological crutch. Wouldn't you rather explain to some waning flame that you're leaving her (him), Earth, and the Solar System itself to colonize **Cha-Zhula IV** (four)- instead of "BD+21o0581-IV"?

Science-Fiction writers *could* begin such a custom of translating #s to names *now*, leaving the IAU to follow. *Engage!* <<< **MMM** >>>

BARNARD's Star

AND THE SEARCH FOR EXTRA-TERRESTRIAL PLANETS

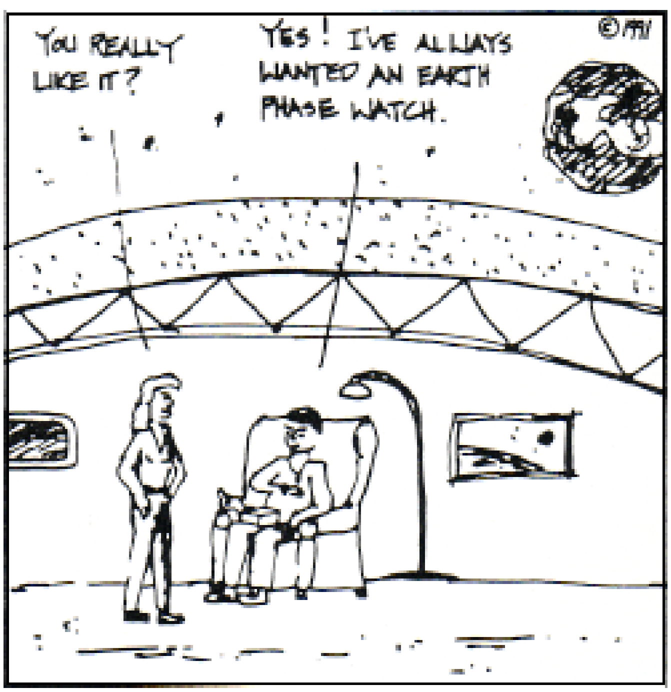
[Cf MMM #36 JUN '90 & MMM Classics #4 "PLANETS around Other Suns"]

Dr. George Gatewood of Pittsburgh's Allegheny Observatory has been searching for gas giant planets around nearby red dwarf stars. We called him 3/21/91 to learn of his progress and he is ready to make a **"mild" statement about a "positive finding"** for Barnard's Star, which at 5.9 light years (1.8 parsecs) is our closest stellar neighbor after Alpha and Proxima Centauri, and our solitary Sun's closest solitary neighbor. There *is* an observed wobble "just outside the margin of error" and the "coming six month observing season could provide confirmation". - PK

[Barnard's Star is a red dwarf star with a spectrum of M5, and a luminosity 1/2200th that of the Sun or some 6 times that of Proxima Centauri. Its suspected planetary system should consist of gas giant planets only. (cf. MMM #44 p. 7 col 2, Article on Proxima Centauri 2nd ◊ [this Classics volume, above, page) as our title font above attempts to suggest.]

[Barnard's Star was the suggested destination of the British Interplanetary Society's ground-breaking design study for the **Orion Inter-stellar Probe**. The reason it has a name, despite being so inconsequential a star, is that it has the highest Proper Motion ever noted, changing position relative to the background of 'fixed' stars at the fastest pace yet observed.] - <MMM>

HARVEST MOON by Andy Weber



SLuGs Abstracts

Note: In these issues of MMM, there were short articles or abstracts about innovative approaches to a number of space technology issues, contributed by SLuGs, Seattle Group studies. We would have liked to have republished some of them, but SLuGs retained the copyright privileges, not MMM, and we are not able to contact them.

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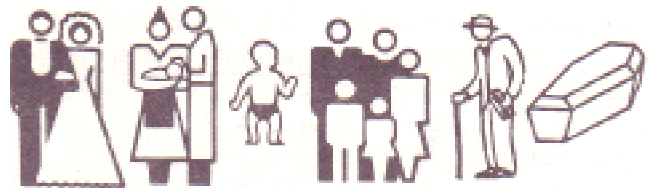


"Plymouth" storyline highlights key question

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

"PLYMOUTH" TV MOVIE

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

AIRED by ABC Sunday, May 26,1991

SYNOPSIS from Columbia Pictures Entertainment Inc.

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

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

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

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

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

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

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

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

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

EDITOR'S COMMENT: How does it all turn out? You'll have to watch if and when it is aired again, or get a homemade videotape. This is the first Sci-Fi movie (made for TV or not) which adopts the premise that space is a place to get resources to help solve problems on Earth. All the right buttons are pushed and the artistic and scientific license is minimal, especially in contrast to everything put on screen prior to *Plymouth* At a special screening for a large portion of the 750 attending the International Space Development Conference in San Antonio, the wave of applause and cheering that swept through the audience at the conclusion was verdict enough. This was a crowd weary of Star Wars special effects and monster of the week series, a skeptical crowd which Writer/Director Lee David Zlatoff won over with few reservations.

A movie like this does a lot to correct the unrealistic expectations and gross misconceptions of a public used to Star Wars, Star Trek, Space 1999, and Dr. Who. Chapters might want to get hold of a videotape of "Plymouth" to show to appropriate audiences. Why not throw a Plymouth Party for a video showing and invite your escapist Sci-Fi friends?

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

ABC TELEVISION
Attn.: President ABC Entertainment
2040 Avenue of the Stars, 5th floor
Century City, CA 90067

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

NATIVE BORN

We can't wait to see if the Moon is "safe for children". Until we're sure that the 2nd native generation is healthy and fertile, we won't *know. Delay will be self-defeating.*

By Peter Kokh

In the recently ABC-aired Disney movie about a pioneer lunar mining settlement, "Plymouth", the central drama was the emergency dilemma of whether to return a pregnant pioneer to Earth, risking the unborn fetus in a high-G descent, or to allow her to bear a child on the Moon that might never be able to survive on Earth. Indeed, birth of the first human offspring outside the womb-world (Birth Squared!) will be a momentous milestone, easily eclipsing any mere demonstration of hardware and technology. If we are to build a system-faring civilization, sooner or later pioneering humans must forsake a return to Earth and begin to raise families, to live and die in space. As obvious as that seems, many of us cling to pathways of realization that are most unlikely to allow such a natural development.

There are pro-space people and there are pro-space people. The conservative peer-conscious shadow-fearing space-proponents who abound in high places see space as an arena for technology demonstration and ascendancy, for national prestige, and yes, for exploration, robotic and even human. They do *not* see it as a place for out-settlement, for a cradlebreak from Earth. That's something left to Trekkie fandom and other wild-eyed crazies like ourselves.

As long as our frontier-blazing activities are guided by the official wisdom of politicians concerned first and foremost with covering their butts with their similarly fretful and risk-shy constituents, its hard to see how such a decision to go ahead with a pregnancy and birth on the Moon could every be sanctioned. Those who are not personally accepting the risk cannot be expected to have anything but a distorted perspective. And so there will be calls for many years of animal experiments, to see how they survive, mature, and breed, and if their offspring are fertile - above all to see how well Moon-born animals survive the return to Earth. But getting our feet wet, experimenting with real humans by allowing them to do what comes naturally - heavens forbid! [No! *Heavens demand!*]

It is the pioneers themselves who must accept the risks, and who can be expected to welcome them fearlessly. "Plymouth" is realistic in that official sanctions and taboos will sooner or later be ignored or foiled, and secretively or not, the first human child *will be* conceived and born in a lunar outpost with everyone a part of the conspiracy to keep it secret until it is to late to foil. Sometimes it is necessary to force an issue with a fait accompli. Politicians like mules, beg to be hit between the eyes with a 2x4.

The problem is, as "Plymouth" brings out so well, getting over the hurdle of trepidation and endless what-if worryings to cross the threshold of *commitment to settlement* - not outpost or garrison - *settlement*. In the rebellious tradition of the Heinlein who wrote "The Moon is a Harsh Mistress" and the erstwhile Bova who wrote "Millennium", there must come a time when the pioneers seize their own destiny, and accepting all risks, knowingly plunge ahead, consciously burning their bridges behind them. While the first childbirth off Earth will be a real milestone, the underlying assent to destiny by the pioneer community will be The Milestone with a capital M. This is a step no colonizing Earth government is likely to advocate or bless. Indeed aversion to such a development may be treated as a litmus test of political correctness on the part of would-be pioneer candidates, in government efforts to avert such a turn of events.

As to animal tests, experiments with small creatures with relatively fast life cycles, using artificial fractional gravity in orbital facilities, should give us an early indication of any potentially showstopping disorders of physiological development under Moon-like conditions. These are unlikely, to say the least.

But in last analysis, we can't know for sure if the Moon is "safe for children" until we bear them there, watch them grow up and mature and have their own children, and see how well the second native-born generation does. For some undesirable traits might not show up until then. Some 20 to 40 years into the commitment to settle, the verdict will be in. For most of us, it is simple a matter of choosing to believe the most favorable outcome. The pioneers who choose to go and gamble with the rest of their lives and those of their yet unborn children, will be of like mind. There is no shortcut from here to there. "There is only do".

But why should this daunt anyone? After all, we are all involved, every last one of us, in a similar high stakes gamble that we can continue to exist as a technology using species in long-term harmony and equilibrium with our host planet - something we can't know for sure without the risks of trying.

Will native-born Lunans grow tall and lithe? I don't know. Americans of our day are much taller than our ancestors, but because of a change in diet rather than gravity. Will Lunan children and the adults they become be muscleless featherweights? This is unlikely. For mass and momentum remain the same. The likelier outcome is that musculature will be different, not less.

What about their cardiovascular circulatory systems. It will take less heart to pump blood from legs to head, but the same amount of heart muscle to power exertion in work and sports. So there might be a problem with the inactive child and sedentary adult, but not likely with those whose physical life is full.

Lunan sports will likely be new creations rather than caricatures in sixthweight of sports familiar to the Earthbound. Such sports will play to the peculiarly lunar mix of one sixth gravity and traction versus full normal momentum. Isometric exercises will be more important than wieghtlifting ones. Will the attempt, by those wanting to leave Earth return options open, to retain hexapotent (Earth-normal) muscle tone result in grotesquely exaggerated physiques, at least by the new Lunan aesthetic standards?

Certainly the image of the ideal male and female physiques will shift dramatically as the new native born generation comes of age and becomes numerically larger than the immigrant population. Miss Luna and Mr. Luna will not likely appear on the same stage with Miss Earth and Mr. Earth. The pretentious Miss and Mr. Universe pageants may disappear.

Lunan standards of grace will show themselves in new dance forms, popular, ballroom, and pseudo-classical and modern ballet. You'll be able to look at someone and know at once if -he is a native-born Lunan, but that -he is human, there'll be no doubt.

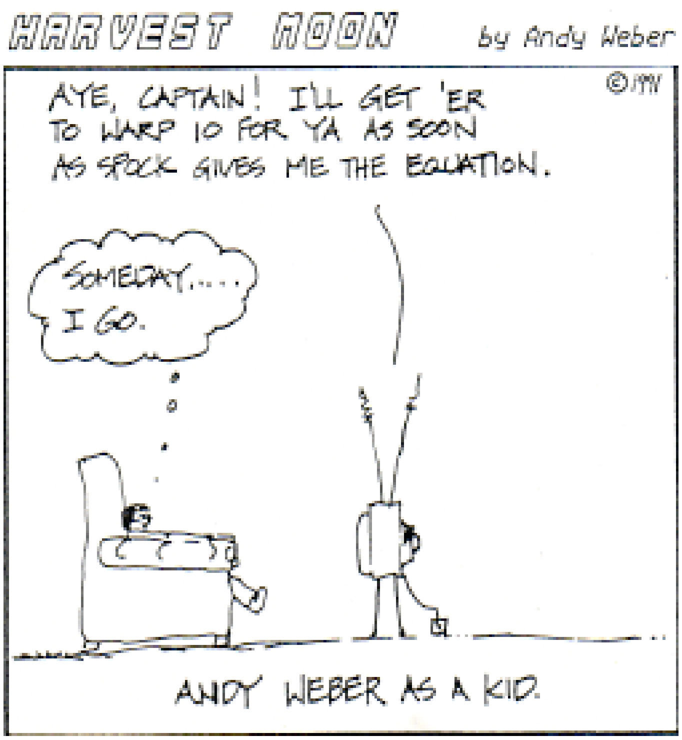
After the first few years of settlement-with-children on the Moon, there will be an interesting suspense about puberty and adolescence, but hardly any surprises. The first real drama will be the rate of healthy births to native-born Lunans. How many miscarriages will there be? How many complications in childbirth itself? How many malformed infants? How many retarded? These are all risks that will have to be faced and willingly accepted.

There are those who feel that after eons of evolution to the tune of Earth-normal gravity, Earth-life cannot adapt. But the whole history of evolution is one great saga of adaptability after another. That we have not adapted to another gravity level is simply because the challenge of doing so has not faced us. Our prediction is that it will be no problem. The worrywarts can stay on their 1G space colonies.

But gravity is not the only thing about which there might be legitimate concern. The mix of trace elements in lunar regolith and the agricultural soils derived from them will be subtly different. There may be deficiency diseases preventable by mandatory intake of dietary supplements and vitamins manufactured on Earth. There may be some level of chromium-toxicity, varying in seriousness from locale to locale. Careful choice of a settlement site considering agricultural needs should prevent severe incidences. Will there be any late-blooming consequences? Probably nothing outside the wide range of dietary variation on Earth.

Again, we must resist the temptation to cater to the perpetually fretful, to those unwilling to cross the mental threshold from the idea of human presence in space to the idea of true human out-settlement beyond Cradle Earth.. Have children we must. And if unlikely medical or genetic disaster does occur? We will have tried. That will be our badge of honor.

[Editor's Comment 2005: In the end, the courageous decision to go ahead with pregnancy, childbirth, and the raising of families will be done only in settlements that are founded outside the sponsorship of governments, especially "democratic" governments who must answer to risk-averse public opinion. One of the unintended consequences of democracy is the eventual rise of gutlessness, the tail wagging the dog.]



FUNERALS

BEFITTING FUTURE SPACE PIONEERS

By Peter Kokh

To date, no one has died in space, though at least ten (Apollo 1 and Challenger) have been killed on the way up and at least four (Soyuz 1 and Soyuz 11) have been lost on the way down. Sooner or later someone will meet h-- end in space, and unless the nature of the death makes the remains unrecoverable, be brought back to Earth for burial with full honors.

The first such deaths are likely to be individual or group accidents due either to mechanical failure or to human error or carelessness. Sudden natural deaths will also possible. As the numbers of people in space grow and the off-planet community becomes ever more and more typical of human society, crimes of passion and even calloused murders of convenience will occur. Slower acting diseases will take their toll, even after early diagnosis, as people decline passage home "to die." Some deaths will be in the line of duty, even self-sacrificial. Others will have no apparent "meaning".

From time immemorial, countless numbers of people have met death and been laid to rest far from their homelands. The sea has claimed hundreds of thousands or more. Many a sailor and explorer lies beneath some marker on an inhabited shore on a distant island. Some have even been vaporized in nuclear explosions and scattered forthwith by the four winds. But never has a person been born who has not been reclaimed by the bosom of our womb world, Earth.

There is a steep psychological threshold here. Commitment of a person's body to "the void" or laying h-- remains to rest on some alien planet, moon, or asteroid will burst the envelope of our sense of "world". We will have been forced to integrate sterile off planet horizons with those of our fertile parochial oasis. If we define WORLD not as the arena of human life provided by the surface of our home planet, but as the *continuous set of horizons* within which humans live, work, and relate to one another, such a baptismal integration of our planetary circumsolar hinterland into the human world will become natural, easy, and inevitable. Laying someone to rest 'out there', or on the surface of some other world or worldlet will consecrate that place forever more as a human place.

How the remains of an explorer, pioneer, or traveler will be disposed of will depend upon circumstances. *On long deep space voyages,* it will be natural to follow naval tradition and commit the body to the "Void". When storage of the body is convenient and the deceased's preference is known, internment can await arrival on the planet, moon, or asteroid of destination.

On Mars, traditional burial or cremation are likely options. But another interesting possibility - once the pioneer settlement is advanced enough to make it handle the logistics - is to lay the body to rest atop mighty Olympus Mons (75,000 feet high) under a canopy of UV resistant glass (to prevent blackening of the flesh) and allow it to freeze dry or desiccate naturally in the near vacuum and deep cold beneath the ever-shining stars - a "desiccatorium".

But *on the Moon* and similar volatile-impoverished worlds where, a) there is an established pioneer settlement encradled in a tightly recycling biosphere and where, b) volatiles are of communal economic necessity considered "rented" not "owned", options will be more constrained. A settler of means, whose estate can afford the replacement cost, at current market-determined values, of the exotic/ precious elements invested in the body and who so desires, should be able to be "wastefully" buried Old Planet style. While this should be legal, there is no guarantee that one's fellow settlers will not look on such a choice as obscene and insensitive. Instead the common course will be cremation, with return to the "atmospherule" of CO_2 and water vapor.

As to the unconsumed *ashes,* even though they are not as precious as the C, H, and N which constitute the bulk of the body's mass, are a resource still. Again, it should be legal to place them in an urn for placement in a private or communal memorial repository. But a more popular and acceptable choice may be to have them spread on a communal memorial garden - not a garden of vegetables, but one of flowers, with no purpose but to add color, scent, beauty, and an island of peace to the pioneer community.

What if someone wishes a more utilitarian disposition? The settlement is very likely to contain experimental agricultural plots where new and improved Moon-hardy varieties of vegetables, cereal grains, herbs, medicinal and dyestuff plants are being bred and developed to improve life on the frontier. Having one's fertilizing ashes spread on such non-production experimental gardens might be another choice for disposition with full honor and due respect.

"Dust thou art," etc. Personally, I prefer a rerendering of Genesis to read

"Stardust thou art, and to the stars thou shalt return!"

The point is we are of the Biosphere and the Biosphere shall reclaim us. On our cradle world where the elements our bodies incorporate are everywhere in profligate superabundance, there is no injury to "the plan" in delaying decomposition by either burial or mummification. However, in the tiny biospherules that we'll need to reencradle our existence on volatile-scarce worlds, there will be some real urgency to dust to dust reinvestment. "Banking" one's "rented" constituent elements for generations by traditional burial would be profligate waste, with a high toll on the shared cost of living on adopted shores.

For those of you with substantial means (count me out, but I wish you didn't have to) stuck against your will here on Earth, it now becomes an option to plan your estate to include a trust fund that would pay to have your remains (cadaver, or at least ashes) trans-shipped to the Moon *when* the day finally arrives that a frontier biosphere has been established there. Whereupon your elements can add to the infant bio-sphere's sweet air and fertile soils to contribute to the infant settlement's prospects of prosperity. Why not?

Death is a Fact of Life spelled with a big F. Yet to transcend the finality of one's mortality one only need contribute, create, produce - in short develop one's own talents - thereby *investing in the community of one's survivors,* - be it only anonymously, be it only fleetingly - rather than just dissipate one's years consuming and spectating. We can do so too by rearing and educating, however informally, and so bring life and light to those who will carry the world (new expanded sense) forward when we are gone. It is in choosing how we will extend the significance of our lives beyond their apparent ends, anchoring them in the community at large, that we find identity and give our lives meaning. It is no surprise that those who never give a moment's thought to such concerns also never find themselves, never grow to know who they are. And so it will be on the Space Frontier as well. <<<**MMM**>>>

[Star*Bound] *series continued*

Understanding ~~*Light-Time*~~

In the ordinary theater of human affairs, it is quite practical to pretend that an absolute "now" of simultaneity exists, that distance is distance and time time. As we move out from the surface of our home/ womb world, however, we find ourselves increasingly dealing with distances that can only be traversed - even in theory - at an every less commensurate rate. *Distance Away* becomes the equivalent of *Time Ago* or *Time not yet* To handle such "separations" or dislocations in "space-time" the term light-year and its derivatives have been invented.

It is 1.4 light seconds *one way* Earth to Moon; 3-14 light minutes one way Earth to Mars; 500 light seconds Sun to Earth. Moving out, Neptune is 1/6th light day away/ago and the round trip span across Neptune's orbit is a full light day.

Only comets are known to inhabit reaches a light week to light months in the there-then, and the nearest known neighboring star or star system, Alpha AB and Proxima Centauri, is so removed that it is all of 4 plus years* out of synch with solar time. (The average distance/dissynchronicity between closest neighbors in our part of the galaxy is 6. 3 light years, so we are lucky! Barnard's Star also lies within that figure.)

Imagine ever more remote ranges of space as a series of ONION SKIN LAYERS Considering the minimum time needed for *round-trip* travel/intercourse or for *exchange* of communication intercourse, we might designate these onion skin layers as follows:

CONTEMPORARY SPACE in the sense of Co-Generational, i.e. *sharing the same generation*, describes all space out to 10-13 light years. Within that range, round trip intercourse/exchange can take place within 20-25 years. The ambiguity of the "now" increases from the instant to the generation as one approaches that limit. Within "contemporary" space, so defined, lie such familiar names as **Alpha Centauri, Sirius, Epsilon Eridani, Procyon**, and at the extreme, **Tau Ceti**.

CONSECULAR SPACE, i.e. wherein the ambiguity of the now degrades to the *sharing of the same century*, lie star systems out to 50 light years. Familiar examples are **Altair, Fomalhaut, Vega, Capella**, and **Arcturus**.

CO-MILLENNIAL SPACE, i.e. wherein exchanges of information can be completed within a thousand years, include stars out to 500 LY. *Stars and worlds within this range "share" our universe if we extend the unstated time element of "our" to include 1491-2491 A.D.*

SUB-EPOCHAL SPACE includes the rest of our Milky Way galaxy and its satellite galaxies like the Magellanic Clouds, out to 500,000 LY. We *share only the same sub-million-year relevance.*

Geo-galactic **EPOCH-SHARING SPACE** extends out to 5 million LY, allowing affinity and connection *within the same 10 million year time frame* between our galaxy and the Great Galaxy in Andromeda, M31, for example.

Geo-galactic **PERIOD-SHARING** galaxies lie within 50 million LY from one another. Geo-galactic **EON-SHARING** galaxies within 500 million years from one another, can claim no more than sharing the same billion years.

Beyond that, **BIG-BANG SHARING** galaxies and what worlds they may harbor more distant = dissynchronous from one another than 500 million LY, share no more than all of time itself from the common beginning on.

[So what about "**Parsecs**"? A parsec (about 3.258 LY) is a unit of dislocation taken from parallax measurements that *seems* more sophisticated because it has no explicit reference to Earth-specific measures like the year (it does have an implicit reference to the arbitrary Earth-standard division of the circle into 360°). What astronomers with airs gain by use of the term is more than lost by the dropping of explicit reference to time.]

All of the above by way of a "reality check" for the article that follows. <<**MMM**>>

EMPIRE

One Fortunate Result of the Speed-of-light Barrier is that Multi-Stellar "Empires" cannot exist.

By Peter Kokh

"GIVENS" 1) Neither matter nor information can exceed the speed of light. 2) 'Usable' shortcuts through the fabric of space-time will never be found. You may be an incurable romantic dreamer, unwilling to accept these statements as facts-of-life with a "big F". Self-delusion is your privilege. This discussion is for the rest of us!

*** Rule of Thumb: A 6-months-round-trip time limit on information flow, sets a distance limit for *sustained* effective exercise of authority.** This figure doesn't come out of a hat, but is based on historical experience and precedent on Earth, and it is our belief that it will continue to hold valid as we move out beyond circum-solar space. Beyond that range, simple logistics makes it urgently practical to be totally self-reliant rather than dependent in even the slightest way on the mother civilization, no matter how advanced the parent world, no matter how crude and primitive the settlement or colony or outpost.

In effect, that would set a limit of 3 light months out *MAX!* to any form of centralized authority. While this is 500-some times further out than Neptune & Triton or Pluto-Charon, it is only 1/17th the way to the *nearest* star system. That means that Earth=Terra= Tellus could not even establish an *effective* empire over the Sun's own Oort comet cloud.

Once we send out settlers (likelier in the low-maintenance travel-ready form of eggs and sperm, i.e. genetic materials) to even the nearest stars, they and their progeny will be very much on their own. If it takes nearly nine years (if not much, much longer) for Earth/ Moon HQ to respond to a dire outpost emergency with so much as bare advice, why bother asking, or listening for that matter? The immediate and permanent need for total self-reliance will assert itself rather quickly as we prepare to leave the immediate parochial vicinity of the home system. As a corollary, it would be foolhardy to depart, "forsaking" circumsolar civilization, with anything less than enough personnel or gene pool, seeds or seed bank, tools and information to function as if the rest of humanity no longer existed - or cared (this later a not too unlikely scenario).

While many people appreciate the vastness of space in some inadequate way, very few have any sense of the equally vast, equally distancing effect of time dissynchronization with distance. The further removed in interstellar space-time, the less relevancy to one another can any two oases of intelligent resource-using life share *or maintain*. [See the previous article.]

*** Extra-solar settlement will be only weakly self-repeating.** It'll take each newly settled system perhaps one to several centuries to fully mature as a center of civilization in its own right with enough divertible, discretionary resources and energy to support interstellar repeater forays on its own.

*** Mature off-shoot pockets of Humanity and Gaia-Humanity** (where Earth-native or Earth-derived vegetation and animal life form the imported cradle for settlement in the absence of given suitable indigenous varieties) will effect one another in a totally **multi-centric** fashion, each being the center of out-spreading ripples of information: history, culture, science, art.

*** Living languages** are ever being regenerated by their speakers and drift too rapidly to serve as a means of communications between Alma Mater and Alumnae worlds, light-generations or light-centuries apart, the likely spacing of suitable settlement worlds. Either some frozen dead language, such as Latin, or some totally new construct especially tailored for efficient and unambiguous radio-transmission - in either case with absolutely pre-fixed vocabularies would work best. Such an immutable Lingua Franca must be agreed upon *before the first star-bound settler ship leaves* our Sol's system, and be treated as sacred, in effect "revealed", set forevermore. New terms must be transmitted as cumbersome paraphrases of the originally agreed upon vocabulary. *Otherwise communication will break down irretrievably, progressively becoming mutual gibberish.*

*** All this means that there can be no interstellar "empires"** in the sense of *structured* constituencies in which *authority* spreads out from a *center* - other than the 'authority' of the common petrified language. The Mother System might be tempted to reserve to itself a sole and privileged right to add new terms to *the* unifying tongue, but such terms would have to be transmitted along with periphrastic definitions for as long as needed to reach the furthest offspring communities. Being "Keeper of the Language", however, is as far as the the mother world's authority could possibly extend. Even this quasi-sacerdotal prerogative could be a bad precedent, one inviting challenge. Those alumni pockets furthest from the home-worlds would have the least reason for confidence that the parent civilization "yet" survives, and would be the most tempted to start rival papacies, thus beginning a slide into a communications anarchy from which there might be no recovery. Alas, if language is to unify, is must be a standard equally respected by all, mother worlds included.

*** The good side** of these rather dim prospects for "interstellar and galactic empires" is that, to the extent even benevolent, i.e. paternalistic, "empires" are necessarily wicked, **we won't have to worry about fighting them, about throwing off the yoke of some "Imperial Authority".** There can be no "Wicked Emperor of the Zenith". Alas, such a wealth of dramatic and exiting "space opera" is forever fantasy - *however much fun* it may be to read!

*** [Gaia-]Humanity may yet spread as "Reaches" or "Diaspora"** [discrete autonomous scatterings] rather than as true structured Empires. Each daughter system will be a unique "*alternate continuation* of Earth history" and of the mother civilization and heritage - each with its own flavor unique blend of unrepeated possibilities. Leaving the vicinity of old Sol will establish an Epoch of Divergence.

For a weak parallel, consider the many English-speaking nations of Earth, all with a very definite feeling of kinship, yet each fully independent and self-guiding. Out among the stars, only the feeblest analog of such a commonwealth could be maintained. Yet the affinity of common origins and pre-divergence cultural wealth will be cultivated as a treasured heritage.

* It follows from all this that in any contacts with the "reaches" or "diaspora" of *other* intelligent resource-transforming races, neither "side" will be able to act, or react, as a unit in any fashion at all. Rather it must be pre-agreed that each settled system is an equally responsible representative of the entire **"family of human** [or other] **civilizations".**

Nor would the "diasporas" of various 'neighboring' species necessarily compete for the same cubic or square real estate. One might prefer G-type suns with planets already sporting indigenous flora and fauna, like Pleistocene Earth. Another might prefer raw pre-Cambrian worlds around hotter yellow-white F-type suns, or seek out endowed but sterile worlds to transform to suit from scratch. Another may prefer systems in which there is ample debris to use as building blocks for space colonies, but without "distracting" planets. Another may prefer the ice-firmamented oceanic Europa-like moons of gas giant planets around feeble M-type red dwarfs or even around isolated brown dwarf substars, etc. etc. Thus it is possible that one or more separately originating diaspora could peaceably interpenetrate the same space-time and be only vaguely aware of one another's existence. But more likely, different families of civilizations are not likely to be neighbors in both space and time at once.

Social, political, economic, and ethnic injustices may persist in all inhabited solar systems anywhere. But whatever the evils lurking within each, relations between systems at interstellar levels are likely to be limited to an "angelic" plane. The virtual quarantine imposed by the vastness of space-time allows little opportunity for anything else.; Contact between independently arisen civilizations will seldom go beyond the most tenuous awareness of the other's existence, with the skimpiest of (rather worthless) surmises about mutual similarities and differences.

*** The one exciting exception to all this is the possibility of "Twin Civilizations"** in well-separated binary G-star systems (say a few light weeks apart) such as Zeta Reticuli. However unlikely in any given case, separate races could arise around each sun in such systems at least somewhere in this vast billion-galaxied Universe. But that they would be near-contemporary to one another, even within a hundred million years or so, is demanding a lot of parallel evolution or compensating divergences. That possibility aside, even a solitary race spreading to a favorable and fertile planet around the other luminary of such a wide twin sun system, would probably be greatly advantaged by having such a sheltered interstellar springboard opportunity, and find itself the more highly motivated to become a truly Star-faring species.

We of Earth are given a great 1-2 boost first by an uncommonly large natural satellite, the Moon, and second by a resource-rich Asteroid Belt - assets that not all otherwise equivalent civilizations may enjoy. If we fail to become truly System-faring despite these handy stepping stones, it would reflect poorly on our species' character.

We have no such handy "training ground" for extrasolar adventures, discounting the Oort Cloud of comets. In this regard, it is statistically more than likely that at least some few other civilizations will have a natural edge on us.

In other words, even such gossamer, ghostlike interstellar networks as might arise rarely here and there throughout the Universe, are unlikely ever to count among their number one spreading out from Earth. If we beat those odds, it will certainly be to our credit.

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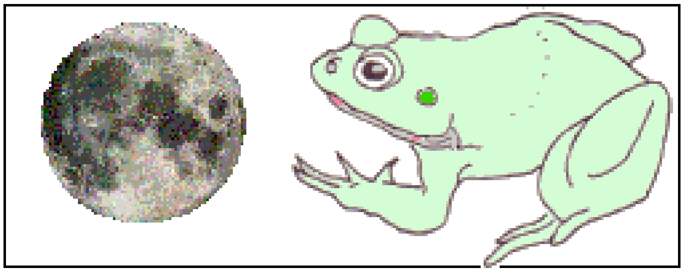


The Role of the Amphibian

Mention "Amphibian" today, and the reader/listener is likely to think of frogs, toads, and salamanders. But now extinct progenitors of this humble subclass of vertebrates intermediate between Fish and Reptiles were a key to Life's conquest of the Land. Might not *amphibious* vacuum-worthy spacecraft as at home roving the moonscapes as plying the space between Earth and Moon play an equal role? Story in "Hostels" below.

NIVICULTURE

Making "economic hay" with SNOW. a model for the 'pioneer mentality' from Hokaido (Japan's north island)

by Peter Kokh

For sunbelters, snow is a curiosity, something that usually happens in the mountains and is good for skiing. Even for those of us in the northlands, snow, while a fact of life year in and year out, arrives in whimsical and unpredictable amounts. But in some snowbelt areas, large winter snowfalls are guaranteed, something people can count on. Hokaido is one of those places. And some people there have begun looking on the yearly endowment as a vast potential resource worth exploiting for more than the Winter Olympics.

Snow is two things: A reservoir of water, and a reservoir of cold. Most people wouldn't look to snow as a practical source of either, because they have other easier, more convenient options. It takes a mind set change, but entrepreneurs in Hokaido are now making tidy profits √ using ice for packing vegetables, √ clean snowmelt water for mushroom growing and irrigation etc., √ underground storage as ice for thermal control and energy production. In other words, they are employing a reservoir/dam analog to put snow to better usage than uncontrolled runoff, "harnessing" the snowfall-melt-runoff cycle

Someday, some of their technologies may find applications on the Mars frontier, both at the edge of the polar caps and with respect to permafrost use. But the real lesson here is one of attitude - the uncommon ability to look for economic potential in the apparently worthless and unwelcome stuff taken for granted by everyone else precisely because it *is* commonplace. Mountain folk treat rocks so, desert folk the sands. It might be expected that lunar settlers will look on the all-covering blanket of loose regolith with a similar contemptuous familiarity. We tend without examination to equate value with scarcity. It isn't necessarily so!

In MMM #22 p4 "!st Souvenirs" [MMM Classics #3], we reported on a similar pioneer mind set among the entrepreneurs and artists of Washington State who were quick to explore the economic and artistic potential of the suddenly abundant Mt. St. Helen's ash - accepted as a useless curse by almost everyone else. The pioneer mentality includes the *habit* of always taking a second look at apparent given disadvantages and handicaps, and a third and fourth look - whatever it takes - until such dubious blessings transform in our perception to reveal hidden opportunities and assets worth exploiting.

The Moon is a world not blessed with rich veins of iron, copper, gold or other ores, offering instead only quasi-homogeneous low grade ores. It is a world with no great reservoirs of water, carbon, or nitrogen. Such resources we require in vast amounts, not just because our life cycle depends upon them but also because we've never had to learn to use them efficiently and savingly. Thus to most, equipped as they are with both the wrong tools and the wrong attitudes, the Moon is a worthless and barren rock. Such people can be dismissed, simply because the real pioneering settlers will "self-select" themselves by their ability to *take* a second look and *see* promise and potential where others see only bleak desolation.

To most people, equipped with both the wrong tools and the wrong attitudes, the Moon is a worthless and barren rock.

There are, of course, several schemes to extract useful metals from the lunar regolith soils and schemes to process usable building materials from them: glass and glass composites [Glax™], ceramics, and cement, etc. But here we'd like to look at ideas for using regolith in a minimally processed way - appropriate technology Moon-style, if you will.

The idea of using regolith for shielding mass is a commonplace. Some investigators take this a bit further and for convenience of handling (*and* rehandling during expansion and remodeling) packing the regolith in sacks presumably brought from Earth, or compacting the soil and then sintering it in brick molds. While this introduces versatile options into the shielding question, it is patently absurd to point to this as a resourceful “use of indigenous materials” - *as if* importing shielding mass in *any* form were ever seriously considered. [Tsk, tsk JSC! Perhaps their recent booklet “Using Space Resources” is aimed at mindless politicos or reporters?]

The pioneer mentality will grade, compact and sinter regolith for light-load paving uses (pathways and porches rather than roads), retaining and shade-making walls, and other uses. Work is already begun to look into the feasibility of simply melting the loose soil either with microwaves or solar concentrators and casting it into useful forms and shapes where strength and performance are not critical requirements.

Lunar artisans, in addition to using craft materials (glass, ceramics, alloys) processed from the regolith will experiment with raw regolith itself from sundry locations for inexpensive glaze, pigment, and other garnish. [See the article alluded to above.] Artisans will find ways to work creatively as well with the unprocessed raw glass microspherules that comprise 10 to 30% of regolith soils.

Lunar architects will make use of commonplace selenological features like craters, rilles, and lavatubes as starting point excavations for building whole settlements, working *with the grain of the Moon,* so to speak. Areas most might look on as impassible mazes of criss-crossing rilles (e.g. the crater Humboldt) might present themselves instead as prime metropolis-building real estate.

Someday, enterprising Lunans will find a way not only to mine Solar Wind “leavings” but to put the occasional intense solar flare radiation to work in various industrial processes. Lunan manufacturers out to get a jump on the less imaginative competition, will find a way to use the Moon’s apparent overabundance of magnesium and calcium, as well as the unwanted tailings from various processing industries.

Lunan chemists and industrial engineers will pioneer a whole repertory of ways to use NaK (pronounced *knack,* a “eutectic” alloy of sodium and potassium, i.e. the alloy formula with the lowest melting point). For NaK is *the* one most abundant regolith-extractable chemical that remains liquid at room temperature and pressures. Similarly, given the scarcity of carbon and hence the expected preciousness of carbon-rich synthetics, new uses will be found for native silicone-based and sulfur-based compounds.

On Mars, those with the right mentality will have an edge in finding resources where others see only naked unreclaimable scenery. Such go-getters will find numerous ways to use the Martian atmosphere (97% CO_2, 3% N_2) as a chemical feedstock for making fuels, plastics, even shielding mass. Others will brainstorm ways to put to use volatile industrial by-products (what we would call pollutants) in the service of slowly transforming Mars’ atmosphere and climate into something noticeably more benign and comfortable. The great shield volcanoes of the Tharsis Uplift will be put to use: the warrens of lavatubes running through their bulk as residential, commercial, industrial, and warehouse space; their west slopes used as launch track ramps; their crater rims as observatory sites, even as “desicatoriums” where the departed can lie in rest forever beneath the stars under UV opaque glass canopies , naturally embalmed in the dry thin cold.

Everywhere throughout the solar system, pioneers - at least those who will survive and persist and go on to thrive - will do so because they have the right mental stuff - the ability to take a second look at the “obviously worthless.” For it is only by finding such latent purchase points that they will be able to carve a place for themselves outside Cradle Earth.

For it isn’t all going to be adventure and exploration. Success will come from trying and trying again, when most would give up after simply looking at the challenge. Ask yourself if you have that kind of pioneer mentality! If so, as Hokaidan snow harvesting enterprise shows, it is a mental tool you can exercise and sharpen right here on Earth, and make money doing so. You can have all the fun of being a solar pioneer right now! As such, even if you do not personally make it into space, you can be a spiritual ancestor of those who do go and make it. How? MMM will continue to point out the opportunities. << **MMM** >>>

LOWERING THE THRESHOLD TO LUNAR OCCUPANCY

HOSTELS

An Alternate Concept for both First Beachheads and Secondary Outposts

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

[A paper presented at the International Space Development Conference in San Antonio, Texas, May 26, ‘91 - *here serialized in three parts* for MMM]

FOREWORD

Our purpose here is to outline an approach which will promote more timely, and wide ranging human presence on the Moon. In the event that the nation does not commit itself to a fully equipped Lunar Base, the hostel approach described herein could offer a less expensive alternative, a minimal but functional “tended beachhead”, a humble yet significant step beyond the Apollo achievement. “Hostel”, a term for sheltered sleeping space available to traveling campers, here refers to a pressurized structure offering minimally and inexpensively furnished “Big Dumb Volume” space for the private and communal use of visiting staff. *The* *concept co-signifies a visiting vehicle to be close-coupled to the hostel for the duration, to provide a complementary "Small Smart Cranny" component.* Such a partnership promises to allow hostel and vehicle to function conjointly as an integral, reasonably complete outpost in support of exploration, scientific research, prospecting, and processing experiments, allowing longer, more comfortable stays at minimum expense. In some later time of expanding presence, roadside hostels would facilitate safer, more regular travel between fully equipped distant outposts or settlements across the globe. *By not duplicating* equipment and facilities that are standard equipment aboard the visiting spacecraft, both the total amount of cargo landed on the Moon and the number of crew EVA hours necessary for establishing a given level of capability, are minimized. Thus the hostel approach has the potential to keep the economic threshold for an initial operational beachhead significantly lower than in other mission paradigms.

Our objectives are four:

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

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

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

I. THE VISITING "AMPHIBIOUS" VEHICLE

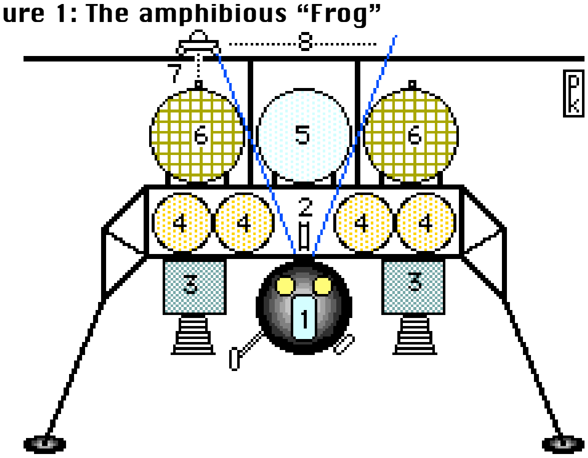
Design Constraints

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

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

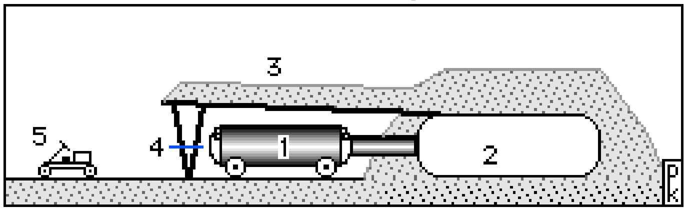
To highlight the amphibious space/surface character of such a vehicle configuration, we have dubbed it the "frog".

Figure 1: The amphibious "Frog"



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

Generic Sketch of Hostel Concept



Frog vehicle docked/coupled to Hostel under shielded open-vac canopy for duration of crew visit. 1 Frog 2 Hostel - 3 Canopy - 4 EVA airlock - 5 Open-vac rover

Frog vs. Toad

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

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

[One criticism of our frog concept brought to my attention at the conference was that, as illustrated, it involved a pair of widely separated engines, one to either side of the centrally suspended mobile crew pod, introducing potential instability if either engine had to be shut down for any reason. Our response is simply that there is so much to be gained by using frog-like vehicles - *however* they be configured - that it is very much *worth the troubl*e to find or develop engineering work-arounds of this problem feature (e.g. a single top center engine with the exhaust split between pod-flanking exhaust bells). By hook or by crook, there has to be a way! - PK]

Outfitting constraints

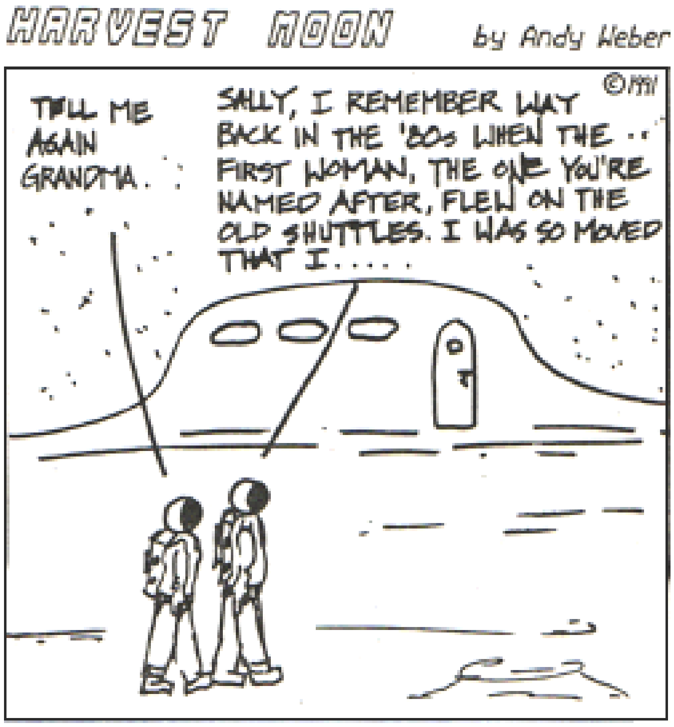
To play its part, the coupling vehicle be outfitted in a way that the capabilities it offers are complementary to those offered by the hostel shelter. It would seem that the repertoire offered would vary according to the customary length of trip for which the vehicle was designed. The possibilities suggest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

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

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

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

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



COLOR, WITHOUT DYES

NATURALLY COLORED LUNAR COTTON

[Based on an article from Organic Gardening sent to MMM by Andy Reynolds, Rochelle, IL - *much thanks!*]

If cotton breeding work now well underway in the Southwest continues to yield results, future lunar farms need not set aside premium growing space for dyestuff plants. Sally Fox, a California cotton breeder, is developing a suite of cotton plant strains that produce 'naturally colored' fibers. [Ed. Egyptian cotton has a natural tan khaki color. But the article mentions she started her project after noticing the "beautiful, naturally brown fibers of insect-resitsant cotton".] So far she has produced a green variety in addition to a wide range of rich brown to yellow-tan hues. She is now working on a blue, a yellow, and a lavender.

Client organic farmers in Arizona and Texas are boosting production in addition to Fox's own 30 acre California plot. Some clothing manufacturers are exited about the idea of eliminating bleaches and dyes. Clothes, sheets, and knits bearing Fox's *Foxfiber* and *Colorganic* trademarks should start appearing his fall.

A Catalog of naturally colored cotton yarn is available now for $3 to Natural Cotton Colours Inc., P.O. Box 791, Wasco, CA 93280. Sorry, but the work is proprietary and seeds cannot be supplied to amateur cotton farmers.

This is exiting news for future lunar pioneers. Saving acreage is the least of it. For the use of even organically grown natural dyestuffs would require a definite water set-aside in a closed-loop setup if yarn, thread, and bolt dying is not to burden the relatively small and fragile settlement biosphere.

In "Apparel: Everyday and Occasional [Made on Luna] Clothing for the Early Settlement" MMM #13 MAR '88 [MMM Classics #2] we forecast just such a possibility. We went beyond the scope of Fox's work, however, to suggest genetic surgery to splice in the genes for indigo (organic blue jeans!), henna, carotene, chlorophyll, etc. It should be very gratifying to anyone aware of the enormous challenges implicit in the idea of a viable lunar biosphere to see such work actually underway and bearing results. <<< **MMM** >>>

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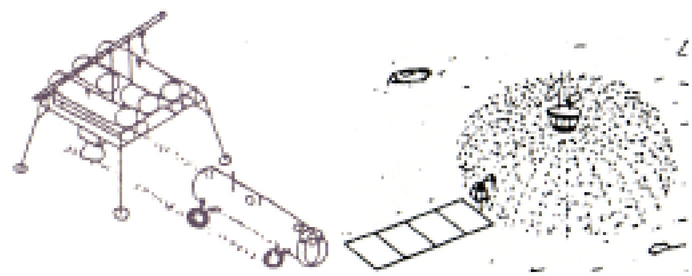


The Magic of Symbiosis

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

LOWERING THE THRESHOLD TO LUNAR OCCUPANCY

HOSTELS

An Alternate Concept for both First Beachheads and Secondary Outposts

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

II. THE HOSTEL'S SHARE OF THE WORKLOAD

General Philosophy

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

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

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

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

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

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

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

Gray Areas

Before we consider how in the concrete such liberal campspace shelter can be offered (that is, building materials, construction methods, architec-tures, and deployment options), we wish to consider some gray areas, facilities and outfitting whose proper placement - in the coupled visiting craft *or* in the hostel space - might be debated. We did not attempt to reach definitive answers. But in each case we list considerations that seem pertinent.

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

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

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

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

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

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

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

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

(4) Thermal Management Systems: This need includes tasks that could be appropriately apportioned between the partner elements. With suitable architectural attention, the hostel could be built and shielded to be thermally stable. Between occupations, the hostel could either be designed so that the interior temperature falls to that of the the surrounding soil blanket (-4°F or -20°C). Alternatively, the hostel could be designed to harvest and store heat from dayspan sunlight so as to coast at some higher but still level still on the cool side but from which recovery to (and maintenance of) comfortable room temperatures will be easier and quicker. Most of the activities for which the hostel space is designed to make room should generate little heat. If the coupled vehicle is parked under a shielding canopy, extensive heat rejection arrays for excess heat generated within might likewise be unnecessary. But if a thermal surplus is expected nonetheless, the radiators indicated would best be a hostel feature, easily integrated with a solar array, or possible placed on the permanently shaded underside of attached ramada areas. Meanwhile, the control apparatus could be housed in the visiting vehicle if it doesn't require much space, since the vehicle already houses ventilation and air quality apparatus which would have to be integrated with the thermal management system.

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

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

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

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

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

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

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

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

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

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

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

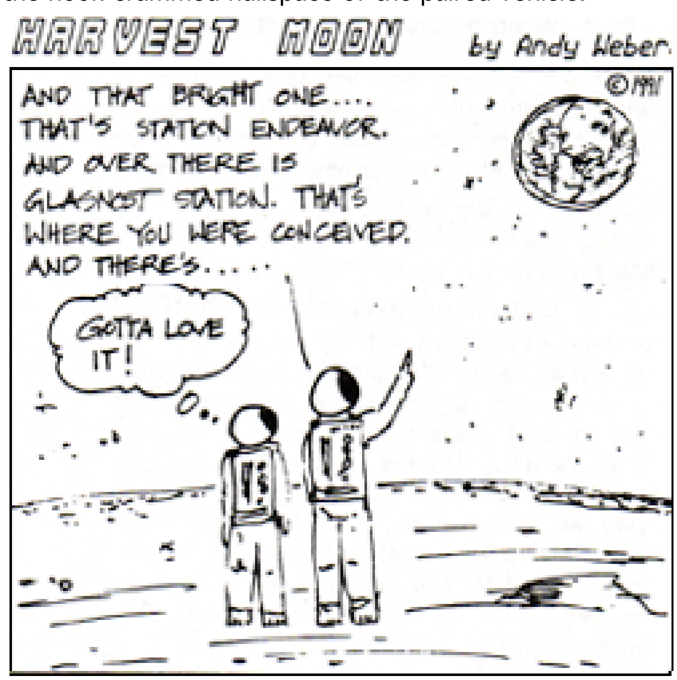
(9) Exercise Areas and Equipment: These are best placed according to the nature of the activity in question. While some daily ritual types of exercise need little room and can be performed in a compact exercise area within the vehicle such as the wardroom area, other exercise routines are space-hungry; to provide for these, any portable equipment needed could be brought into the hostel and left there. The hostel's interior spaces and overall architecture might conceivably be designed and arranged to incorporate a banked peripheral jogging track, or even a "sixthweight" caricature of a bowling lane. A billiards or ping-pong table, even a handball court are imaginable, given enough cheap dumb volume.

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

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

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

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



The Above Frog/Hostel Division of Labor is Shown in Schematic Form Below

FROG VEHICLE FUNCTIONS	INITIAL HOSTEL FUNCTIONS
Communications Center	Bedrooms, Lounge, Office, Chapel etc.
Navigation/Systems Computer	Main antenna, possible ham equipment
Fuel Cells for use when decoupled	Personal computers in quarters
Electrolysis equipment, LH2, LO2	Main power generation equipment
Air quality and ventilation	Surplus compressed H2, O2
Thermal management controls	Departure dehumidify/bake cycle
	Main heat-shedding radiator bank
EVA airlock	Open-vac rover
Water recycling, treatment	(No initial plumbing, drainage)
Water closet, shower	Plumingless toilets, waste banking
Laundry washing	Laundry drying
Galley: meal prep, scrap disposal	Main dining area - all meals
Fresh Food locker	Pantry for standby rations, snack bar
First aid and trauma cabinet	(future diagnostics/major medical procedures)
Isolation berths	Infirmary space
Wet/dry compact workstations	Dry space-needing workstations
Sample analysis, experimentation	Sample sorting, display, storage
Cab windows, both ends	(Panoramic exterior visual access)
	(Interior solar access, heliostat)
In place exercise center	Space needing exercise area
In transit entertainment console	Bedroom consoles, Lunge console
Limited tape/disk collection	Accumulating library, collections

III. EVOLUTION OF THE HOSTEL WITH USE

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

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

(2) A Farside Astronomy Station: Our recommendation is different for a hostel designed to serve remote infrequently tended installations such as a Farside Advanced Radio Astronomy Facility (FARAF). Such an installation may well follow, rather than precede the establishment of an original permanently staffed nearside Moon Base, so that the latter could be an advance logistical support node for the farside operation. Following this scenario, the hostel should be designed from the outset with planned expansion and evolution towards permanent autonomous staffing in mind, and an appropriate architecture chosen accordingly. Indeed, it was to show that there *is* a happy middle ground between the vehicle-tended farside minimalist installation envisioned by NASA and the permanently staffed major installation the astronomers would like, that we set about to develop the hostel concept in the first place.

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

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

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

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

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

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

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

In all cases, docking apparatus should be pre-standardized. If we are indeed going to develop the Moon as an integrated part of a greater Earth-Moon or circum-solar economy, the solitary first beachhead must give way to a multi-site world, and hostels will be at the forefront of that global expansion and acculturation. Any visiting vehicle, frog, toad, or coach, should be able to couple with any hostel.

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

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

TRAMPOLINES

Exercise on the Space Frontier

By Michael Thomas, Seattle L5 Society

As we all are aware, one of the major challenges of long term space habitation is maintaining physical fitness. Muscles atrophy, blood counts drop, and bone mass begins to dissolve away in the absence of Earth normal gravity. Of course, there are treadmills, exercycles, elastic penguin suits and other devices to maintain fitness: but who wants to run on a treadmill for 2-4 hours a day like a caged hamster? Such a draconian schedule only contributes to the already significant psychological problems of long term space habitation.

The padded "jogging track" on Skylab was somewhat an improvement over treadmills, but in the absence of artificial gravity via rotation, it's usefulness as a fitness aide was quite limited. What we need is to create a little excitement: something people will *enjoy* doing. My suggestion is to provide repeated bursts of acceleration, in a most novel form: trampolines.

Since acceleration, when constant, and gravity are indistinguishable, anything that provides acceleration serves for the duration as a source of artificial gravity. Impact with a trampoline results in rapid deceleration and then rapid acceleration in the rebound. While your body presses against the trampoline, you feel a pressure akin to gravity - for the moment. This puts stress, although inconstant, on your bones and muscles as though you were in a higher gravity environment. And while these periods of gravity stressing are brief, they are also numerous. An hour of play could be the equivalent of a few minutes in a more gravid environment depending upon how hard and frequently one impacts the trampoline.

On Earth, one jumps up from a trampoline, then falls back down to it to rebound again. But in a microgravity environment, this would not be practical. One would jump so high that it could be minutes or more before one fell back down. Even on the Moon, a single jump would take one many meters high, and it would be stretched moments before hitting the trampoline again.

The solution to this temporal exaggeration is simple. Have a trampoline *floor* and a trampoline *ceiling!* This way one is jumping from trampoline, to trampoline, to trampoline,etc. With double trampolines, the force of the impacts would not be determined by the gravitational environment, but by the mechanics of interrupted momentum.

Two factors would come into play: the stiffness of the trampoline and the strength of the jumper, or how hard the jumper pushes against the trampoline while in contact. Accelerations of two or three Earth gravities might be readily achievable by fit persons, even in microgravity. And research into the medical condition osteoporosis (bone demineralization) indicates that such brief accelerations would likely be effective in maintaining bone mass if practiced daily.

There are many possible variations on this "space trampoline" idea. Imagine if Skylab instead of just having a padded track around its circumference, had a cylindrical trampoline so that it's inhabitants could have leapt across its width. They could have maintained a higher level of fitness and had fun doing it. Now imagine that the trampoline were rotating: that it were a centrifuge-trampoline. That would be more of a challenge (and more fun perhaps) to master.

[Editor: If a pair of trampolines were rotating about a common point, the action could be quite complicated, dizzying, and subject to corriolis forces. A lot of experimentation would be needed, in space itself, to come up with a combination that worked.]

Another possibility is a spherical trampoline, held rigid by air pressure, or by [ties to] a[n exterior, larger] geodesic frame. This might be located at the hub of a rotating structure. Or a trampoline court or gymnasium, in which not only the floor and ceiling are trampolines, but the four walls as well. Such a court could be as small as a few meters on a side, or enormous where space and resources permit.

While very stiff trampolines providing high accelerations should be appropriate for very fit persons, less well conditioned individuals could avail themselves of softer, more elastic trampolines that provide lower accelerations for longer periods of time. Trampolines might even be designed for adjustability of their stiffness to suit various individual's needs. Many sports might be played on trampoline courts, but I suspect many people would enjoy the thrill of just leaping. **<MT>**

MMM #50 - NOV 1991

LOWERING THE THRESHOLD TO LUNAR OCCUPANCY

HOSTELS

An Alternate Concept for both First Beachheads and Secondary Outposts

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

IV. HOSTEL-APPROPRIATE ARCHITECTURES

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

Hostels Pre-built or Prefabricated on Earth

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

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

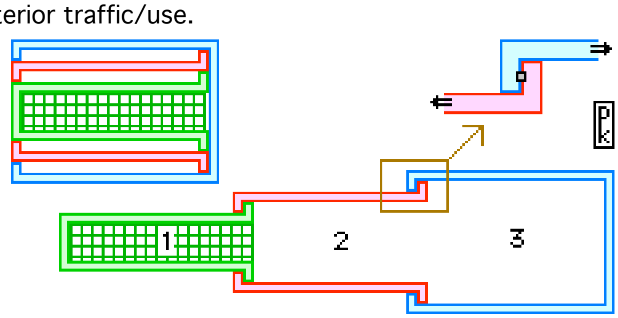


Figure 3A: Telescopic Module: The thickness of the sleeve walls, and the amount by which one is smaller than the other, is exaggerated to show detail.

Alignment would be preserved by the simple expedient of a key/keyway feature with keys on the outer flanges and keyways on the outer surface of the inner sleeves. Outrigger skid-dollies attached to the smaller ends and the outer flanges of the widest diameter middle sleeve, riding freely on a pre-levelled compacted gradeway, would midwive the deployment. Airlocks or docking ports could be placed at either end, but only the widest sleeve could have a side-mounted protrusion. A pair of bidirectionally expanding units could turn this to advantage to conjoin "H" style.

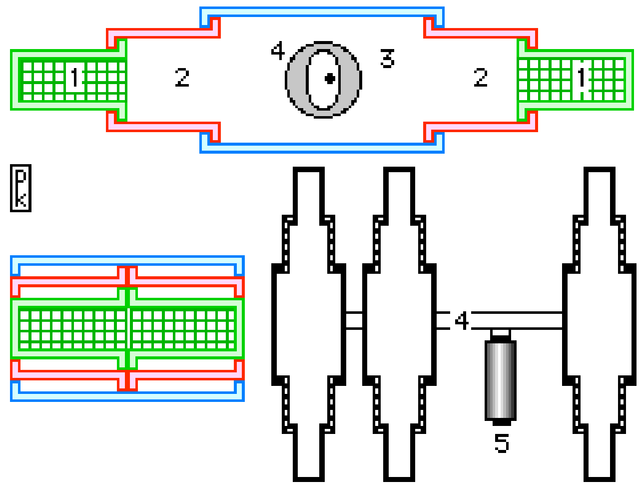


Figure 3B: Bi-telescopic Module: [4] connector tube. [5] docked frog, perhaps under a shielded canopy..

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

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

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

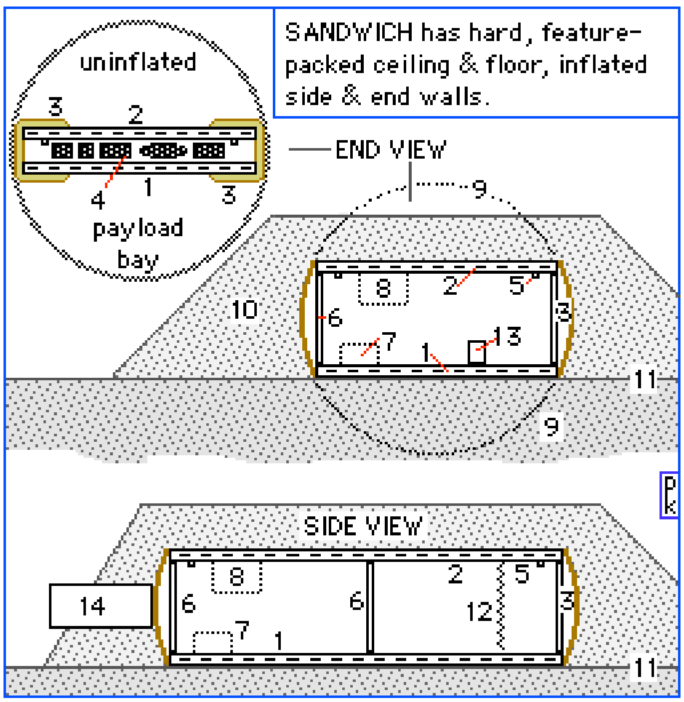


Figure 4: The Sandwich: [1] Floor module with pop-up built-ins. [2]Ceiling module with pull-down units.
[3] Inflatable sidewalls and end walls..
[4] Collapsed loose furnishings
[5] Cove-lighting tubes or bulbs
[6] Contingency support poles & utility chases
[7] Representative floor pop-up feature
[8]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

b) While the great advantage of the sandwich design is that it offers a stable flat footprint and a ready to use flat floor, it offers little more than half again as much space as a rigid module designed to travel in the same cargo hold. Another configuration, which we've dubbed the "slinky", features rigid feature-packed cylindrical end caps connected by a cylindrical inflatable mid-section. Here instead of multiple circular ribs and worm-like segmented lobes, we strongly suggest using a continuous helical rib spiral, as this helical design choice offers an elegant opportunity to build-in a continuous electrical service run along with other utility lines and lighting strips within this skeletal "monorib."

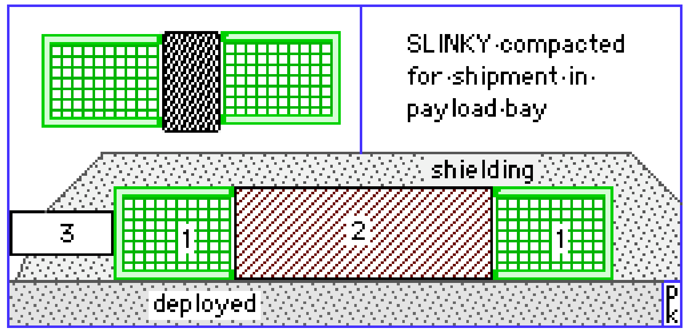


Figure 5: The Slinky: [1] Pair of rigid end caps, outfitted with build-in features and equipment.[2] expandable slinky module (unfurnished). [3] docking tunnel.

c) Next we came up with a novel wide-floored lunar "quonset" idea. It has a stable footprint and favorable width to height ratio. While all the built-in features would have to be floor-housed pull-ups, this design offers about two and a half times as much floor space as the "sandwich" for the same payload bay space. The inflation-reinforcement of a triple slab hinged floor is a design innovation that offers opportunities for crawl-space storage, utility space, and ventilation worth pursuing. A telescoping vestibular passageway for vehicle coupling could be built into one or both inflatable end-walls as illustrated.

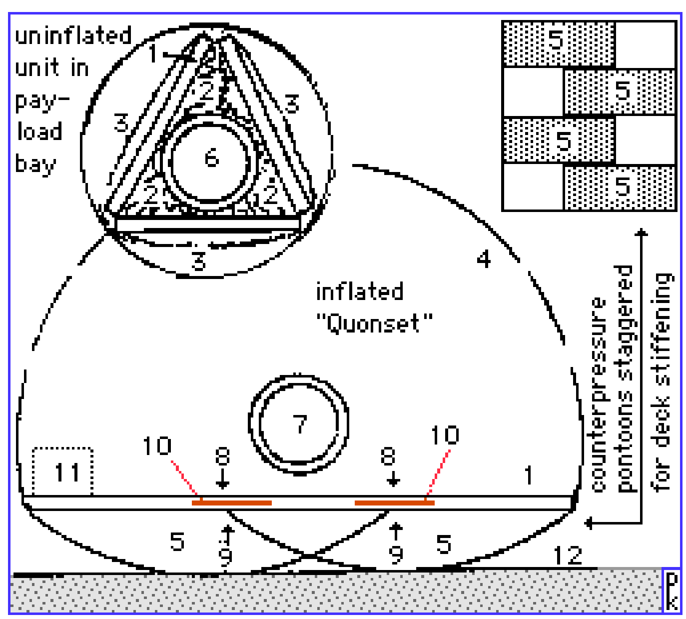


Figure 6. QUONSET:
[1]Hinged 3-section floor deck.
[2] uninflated quonset roof/wall
[3] uninflated floor support pontoons
[4] inflated quonset roof/wall
[5] Inflated floor support pontoons
[6] In transit position of docking module
[7] Docking tunnel in end wall
[8] Downward air pressure on hinges
[9]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

d) Finally, we sketched a hybrid torus design, dubbed the "donut", with the donut-hole wall replaced with a compact payload-bay sized hexagonal "works" module loaded with pull-out built-in features including top mounted central solar, visual, and EVA access, side-wall vehicle docking port, decking erected from parts brought up in the core module's "basement', complete with a peripheral jogging track.

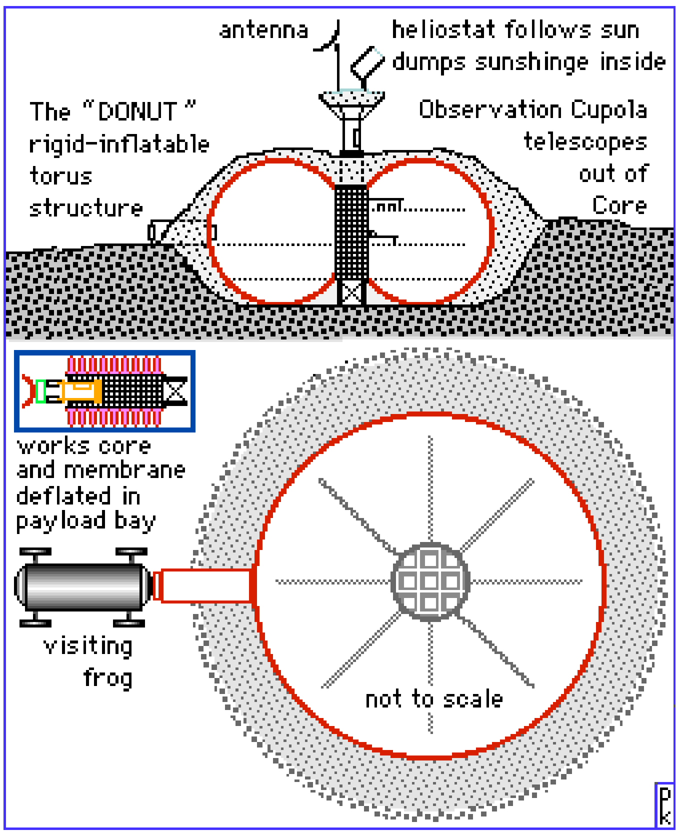


Figure 7: The Donut: This 3 floor model at top is an upgrade of the simpler design in the original paper. Shown is the central works-packed core, optional telescoping observation & EVA tower, antenna, heliostat. Docking tube is at left. In this version, a small crater was chosen to make shielding emplacement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

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

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

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

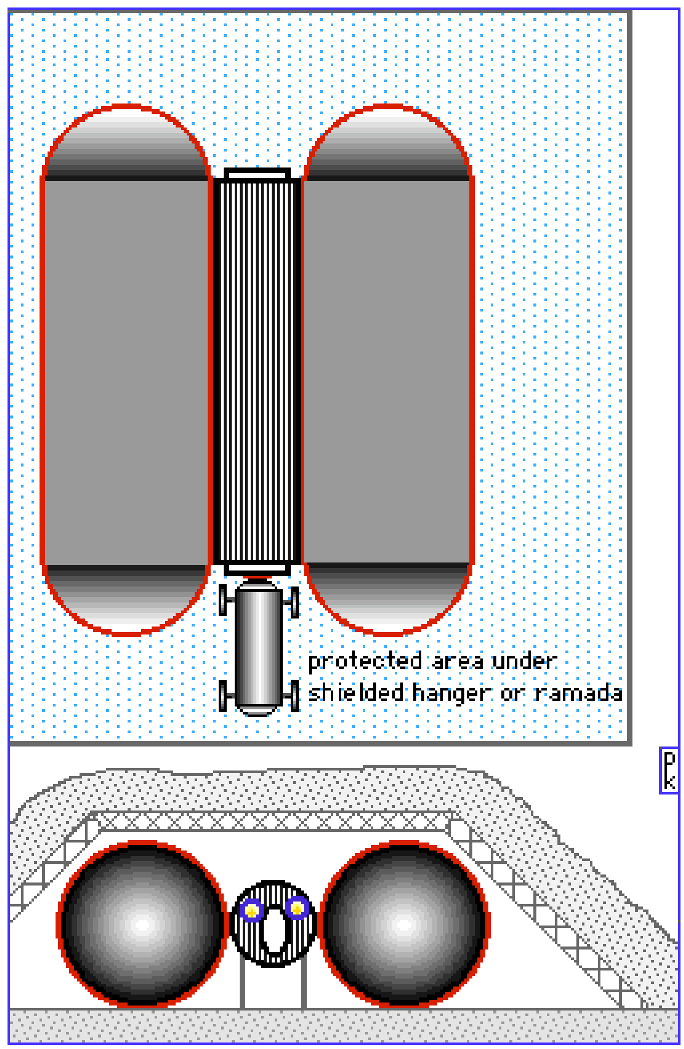


Figure 8: The Trilobite: The works core module could be scaled to a 15' wide shuttle payload bay or to a 27' wide faring atop an External Tank, with inflatable cylinders proportionately sized. Here, the trilobite hoste sits under a shielded hanger, making servicing and expansion much easier.

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

(5) Shielding for Prefabricated Hostels: Since full tele-deployment would be ideally appropriate for these intermittently staffed outposts, ways of covering the hostel with regolith shielding by robotic or teleoperated means should be researched. The needed equipment could be small and lightweight with minimal power, as,working slowly prior to the arrival of a crew needing protection, there need be no hurry to finish the job. Perhaps this task could be performed in such a way that the shielding regolith might be gathered as part of the process of grading and compacting a launch pad and a driveway or taxiway to the hostel for visiting frogs to follow. The basic idea is that the first humans to return to the Moon since the departure of Apollo 17 find a cozy place waiting.

Hostels Built on the Moon of Native Materials

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

CONCLUSION

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

TREES

On the Space Frontier

By Peter Kokh

Recently, a student working on the NASA grant Genesis CAD [computer assisted drafting] Project for Lunar Base & Habitat Design at the University of Wisconsin-Milwaukee's Department. of Urban Planning and Architecture, produced an interesting plan in which his base offering was caped by a dome "*to give place for trees*". A NASA auditor excitedly protested that there was no way we could afford to waste space in such fashion. The student, unabashed, replied that if there were no trees, it would not be a human place, a place fit for human habitation; he stuck with his design.

This little anecdote illustrates a real dilemma. If we can afford to set up a lunar base at all at today's pre-SSTO [single stage to orbit] prices per pound to orbit etc., it may have to consist of sardine cans with perhaps an inflatable annex or two in concession to the need for elbow room. Even if the costs of space transportation fall, spaciousness will still be at a premium until we begin to build added expansion shelter from building materials processed on site (in situ) from lunar resources. This will require getting such technology out of the current laboratory curiosity stage, hopefully before we return to the Moon and start scratching our heads (is anyone listening out there?). The practicality of in situ architecture would be greatly enhanced if we could locally produce low-C [carbon] sealants, to keep import costs down.

But even with new on-line Lunar architecture, pressurized areas will tend to be close-ceilinged, without tree-scale headroom, or more; for the Nitrogen needed as a buffer gas to pressurize extra volume will be a costly import, that is, prior to large scale Helium-3 mining which will yield,. hydrogen, carbon, nitrogen, and other precious gasses as by-products. Of all the "lunar-defficient elements", or LDEs, nitrogen is in shortest supply in comparison to need, the choke-point for lunar operations - not hydrogen as is commonly believed. (Hydrogen, from Earth or Phobos/ Deimos, is best shipped as Methane CH_4, or Ammonia NH_3.)

The student's observation, however, is quite on target. Without trees, we'll have only a caricature of human place, despite the fact that in some desert and plains areas, people *do now* live without them. Trees have played a critical role in the very appearance of mankind. Arms first became differentiated from legs, to the point that bipedalism was the next step, through brachiation, their evolution to fit the needs of simian predecessors swinging through the rain forest.

Much later, trees supplied poles for making shelters, and first allowed us to master rivers and coastal waters. We felled trunks over narrow streams and eventually milled them into bridges. We "dugout" trunks for our first boats, accelerating not only fishing and trade, but giving birth to fishing villages along ancient now-drowned coastlines (end of ice age rise in sea levels). Such villages likely well-predate the better known agriculturally-centered villages of the bronze age. *Trees have been a far more shaping element in our remote past than ever was the cave*. In short, if we ever do come up with an "all-human coat of arms", the tree deserves a place of honor in that design.

All this is over and above the function of the tree in Biosphere I. Second to oceanic algae and phytoplankton, Earth's forests make the greatest contribution to the sweet oxygen necessary to all higher life forms, single cell on up. Forests, even smaller groves of trees, help moderate temperatures, making many areas on Earth more livable. Finally, even lone trees produce shade and serve as place markers.

What place will trees have in baby biospheres? Their dedicated use for ornamental or landscaping needs would be an exorbitant luxury in off-planet towns until the constraints mentioned above are removed. The fragrance of blossoms and the reassurance of luxuriant greenery will instead be provided by smaller plants earning their place through food, fiber or pharmaceutical byproducts, all while naturally recycling exhaled carbon-dioxide into fresh oxygen, and filtering out airborne pollutants that can't be avoided.

Yet, for settlement agriculture, trees remain a highly desirable asset: they'd add greatly to the variety of fruit, syrups, pulp, fiber, and artstuffs etc. - purposes that are less easily satisfied by smaller plants or bushes. Happily, tree "dwarfing" by nursery breeders serving home gardeners has made much progress. Prospects for settlement farms to feature short but fruit-laden apple, orange, pear, peach, and cherry trees (to name a few) are really quite good.

Beyond that, there is one radical proposal to grow nothing but ultra-fast growing trees on lunar or space settlement farms. Called ARBORCULTURE, this scheme would harvest the trees for pulp to feed vat-cultures of microorganisms which would transform this fodder into synthetic foods of every imaginable taste and texture. Someday that pseudo soylent green may well be the most efficient way to do farming on the space frontier.

Meanwhile, living **BONSAI** miniature trees can provide nostalgic ambience for the early pioneers. The Japanese have long cultivated the art of dwarfing trees for room decoration. By controlled pruning and fertilization, trees are trained, not bred, to grow in small pots into caricatures of older, bigger trees. Evergreens, leafy deciduous trees, vine and fruit-bearing varieties are all successfully miniaturized. Settlers can grace their private quarters with them. Room/area dividers can consist of shelf-rows of bonsais. Waist-high setback platforms in passageways can be lined with them. Mini bonsai forests can adorn unused spaces. Pioneers needn't wait to bring along this quintessential human cultural symbiote. **<< MMM >>**

First Bonsai "forest" on MARS (*er,* M.D.R.S.)

On February 8th, 2005, the MMM editor arrived at the Mars Society's Mars Desert Research Station in SC Utah, as part of Crew #34. He came bringing gifts, among them a Bonsai starter kit. The seedling was potted by fellow crewmate Ben Huset of the Minnesota Space Frontier Society. Ben was one of the L5 "colonizers" who, on 9-15-86 helped start the Milwaukee chapter (the Lunar Reclamation Society, publisher of MMM.) He has also had a lot of experience in the farming and agricultural areas.

Our hope was that nourishing this miniature tree would become a tradition at MDRS, a tradition that would be carried to Mars, and, of course, to the Moon as well. The time allowed for incoming and outgoing crews is very limited, however, and "The 1st forest on MDRS" may well get lost among priorities.

The tree survived its first season and is being cared for off season by friends of the Mars Society in nearby Hanksville. **<PK>**