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

Moon Miners' Manifesto

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Illustrations Key:

Four of the many interesting articles in this publication year (see 4 illustrations at right) were:

- **Investing in Fuel Tank Infrastructure in the Architecture of Lunar Exploration**
- **Overhead railroads and cableways**
- **Mars to Stay**
- **Pie in the Sky: The Moon's bounty of elements for building materials as the basis for industrialization**

Other articles of note include:

- LUNAR ENTERPRISE & OPPORTUNITY by Dave Dietzler, (part 5 concl.)
- Lunar Settlements are critical to the "Economic Case for Mars"
- International Lunar Research Park concept introduced
- Lunar Research & Development: top 5 priorities
- Magnesium & Iron
- SPS Materials Alternatives
- Skinsuit "Accessories" may "open" the surface to lunar pioneers
- Space Settlements vs Planetary Surface Settlements
- "Its Not Getting Done" (five parts) by Martha Adams
- Design concepts for the Moon/Mars Atacama Research Station proposed for Northern Chile
- Extracting minor elements from moondust
- The International Space Station as model for an International Lunar Research Station
- Resources of Mare Imbrium and Oceanus Procelarum
- Defining the Lunar Industrial Seed - Dietz 1-3a
- 20 Questions about Resources on the Moon
- Antarctica's McMurdo Sound: History of Growth vs. possible patterns of Growth of 1st Lunar Settlements

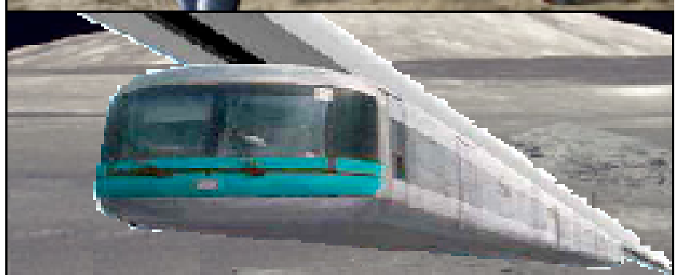
In Addition

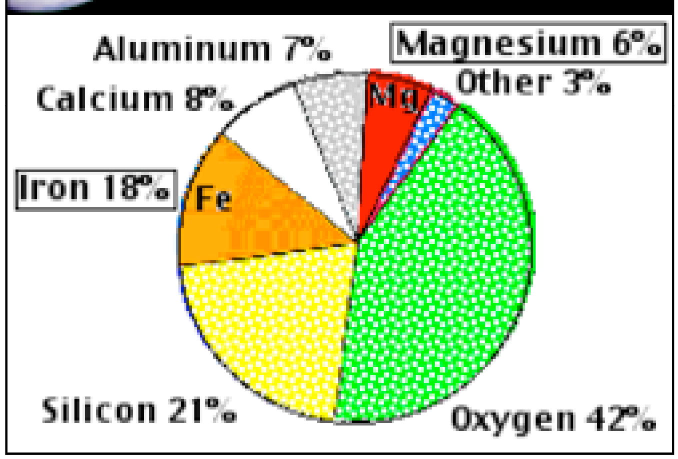
There were a number of Book Reviews.

We do not preplan the article spread in any publication year. Some topics are revisited more often than others. It all depends on the inspirations of the contributing authors.

Check out all the Moon Miners' Manifesto Classic files: www.moonsociety.org/publications/mmm_classics/

Thanks, and Enjoy!





LUNAR ENTERPRISES AND DEVELOPMENT

Especially prepared for *Moon Miners Manifesto*.
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Installment 5 - Conclusion

4.1 Lunar Start-up Enterprises

Back in Exhibits 131 and 132, we indicated the possibilities. First, it will be in building housing and facilities, as well as providing survival systems for the lunar pioneers. These will relate to radiation protection, lunar dust, safety and wellness, water and food supplies, waste disposal, and especially communication systems, both on the Moon and to Earth.

Next the real industrialization processes will get underway – turning lunar soil with its oxides into oxygen and fuel; constructing transportation systems on the lunar surface; installing detection sensors against hazardous conditions, materials and objects, et al. In subsequent stages of lunar development, there will be a variety of undertakings – from scientific experiments and telescopes, to arranging for solar energy supplies, mining helium-3, and a host of necessary activities. The latter will include broadcasting from the Moon, lunar education and training, eventually tourism and settlement services. Should the initial lunar outpost be founded at the lunar south pole to take advantage of its shadowed craters, almost continuous sun, and view of the sun, a second site might be developed at the lunar northpole for s continuous communications center and observatory. Someday these two locations may be connected by a lunar "railroad."

Beginning with the individual responsibilities of lunar project managers and contract supervisors, regulators and administrators will likely growing in number. So will a security system of peacekeepers until a full governance system can be instituted. Whether in ground support services or orbital endeavors, terrestrial systems will have to be adapted for budgeting, funding, accounting, reporting, information management, and technology transfer. This is what we discussed as **macroplanning and management** in chapters 7 and 8

4.2 Earth - Support Enterprises

Obviously, spaceports will play a big role in lunar exploration, as Derek Webber reminded us in 7.2. Whether on the ground or in orbit, they will be critical for more than maintaining and launching spacecraft. Spaceports will be where spacefarers will be initially housed, fed, and processed before going offworld. An emerging market will be expertise in constructing lunar spaceports, beginning with the initial port of entry.. Contractors will be required to build each aspect of the lunar transportation system, from the ground to the lunar surface and around the Moon itself..

In his book, *From Footprints to Blueprints,* Michael Ross examines many dimensions of lunar development and private enterprise. 37 This Canadian engineer reminds us that all lunar activities will require support facilities and services on Earth, to a greater or lesser extent. Sometimes the stakeholders will have the necessary technical expertise within the sponsoring organization. But with increased scope and complexity of lunar enterprise, outside support will become necessary. He forecasts these emerging Earth markets providing

(1) Operational performance on the terrestrial surface;
(2) Monitoring of in-flight performance;
(3) Research and testing laboratories;
(4) Technology transfer consultation;
(5) Lunar-base simulations and mock-ups for testing layouts, ergonomics, and technical functioning;
(6) Facilities and services for lunar spacefarers, whether crew, workers, or settlers and eventually tourists (e.g., medical and psychological evaluation, etc.). To this end, the American Society of Civil Engineers has already recommended establishment of a Lunar Center for Extraterrestrial Engineering and Construction. 38

As always in any orbital undertaking, lunar space suits will have to be improved beyond those used in *Apollo* missions some forth years ago. That complete garment with helmet, gloves, and boots weighed over 200 Earth pounds¸ and today manufacturers can produce a suite of new, light-weight materials with improved life support and communication functions, as well as a radiation dosimeter, such as presently used for EVA's on the *International Space Station*. In addition, lunar surface vehicles and shelters will have to be designed, built, and shipped to the Moon with provisions for complete life support systems therein. Vendors will need to devise mechanism for inventory control, and monitoring, both on the ground and aloft, for all such critical equipment.

Telepresence:

One for the greatest opportunities for private enterprise is to create the necessary communication systems for people to use on the lunar surface, and between the Moon and Earth. The present mission control approach of space agencies will be obsolete by the time lunar operations are underway. Therefore, one promising possibility is the new technology available for telepresence.* To cut down on costly and sometime dangerous business travel, the old technology of video-conferencing has been updated and gone high tech, with increased speed and quality of transmission, as well as improved, high-definition screens and reception. It creates the impression among participants that they are in the same room, though individuals or groups may be very far apart. It would be the perfect communication technology to reduce the distance in cislunar space!

If the R & D were undertaken now between earthkind and spacefarers on the *International Space Station,* then it might be feasible to introduce a working system for the benefit of lunar workers and settlers by the end of the next decade. Such telepresence could not only improve business and management conferencing between Earth and the Moon, but benefit families and friends in both locations to maintain relations. It would be a counterpoint to the isolation and alienation that humans might experience on the Moon, so cut off from their fellows on the home planet.

Presently, the leading manufacturers are Hewlett-Packard and Cisco who have yet to appreciate the market prospects for their technology and services offworld. Hollywood's

* "Behold Telepresence – Far Away but Strangely Personal," *The Economist,* August 24th, 2007, pp. 57-58/

Dream Works is in the emerging business, using telepresence systems to make movies cheaper and faster by allowing creative types worldwide to confer without actually traveling to meet one another. Now imagine if this technology could also be used to transmit to the Moon the latest movies, sports, or entertainment events! The market will be there to capitalize upon in twenty years for the entrepreneurs who start now! Frost & Sullivan forecast that this innovative techno-logy will develop into a $1.24 billion terrestrial market by 2013. Do some "mindstretching" about the market income prospects beyond Earth!

4.3 Lunar Base Location and Expansion

NASA, ESA, and other partners are conducting site searches for the best location of the initial outpost and/or base on the lunar surface. Some consensus is building for the South Pole near "Malapert" Mountains, but site confirmation will come after, automated mapping missions are completed.

Some planners favor a lunar lava tube site that offers radiation protection and a constant temperature environment. There is much continuing, unresolved discussion among the experts on the size, design, and composition of the first lunar outpost. Obviously, much of this material would be prefabricated and have o be initially transported to the lunar surface for assemblage by both robots and humans. Whatever the composition of these first structures, they will be buried largely underground and covered with lunar regolith for radiation protection. Once we move beyond space agency needs for a small crew of astronauts, the base will unfold as more facilities are provided for scientific research, health care, and industrial operations. When the lunar population expands and commerce is underway, undoubtedly there will be satellite structures erected away for that base at other locations on the Moon.

It was encouraging in 2005 when Italia sponsored an international conference in Venice on " Moon Base – A Challenge to Humanity" (www.moonbase-italia.org). But until NASA and its partners issue a Lunar Architecture report possibly before 2010, we can only speculate as to how this generation will proceed with its return and settlement of the Moon. However, the scientific and engineering communities have provided the public with what to expect, as our many chapter references confirm.

We can anticipate a **lunar scenario** somewhat like this: 39

_ A series at start of unmanned missions for the purposes of transporting to the Moon, of robots, cargo, shelter payloads, plus telerobotic lunar rover capable of being driven from Earth or programmed for preliminary lunar construction tasks, such as erection of telescopes and observatory...

_ The first manned lunar landing since *Apollo 17* will initially focus on astronauts' deployment and completing their own outpost shelter; establishment of life support, communications, and transportation systems; inspection of previously placed telescopes; returning to Earth, robotic collections of further lunar soil and rocks for additional analysis (petrographic, chemical, and radiometric);on-site human inspections and evaluations; further emplacement and maintenance of geophysical and astronomical instruments, plus similar precursory activities toward base expansion…

_ Technology research and development by "technauts" trained to begin the utilization of lunar resources, from oxygen and water (H-E extraction), to solar energy and mining prospects (helium-3), to broadcasting special programs to Earth's inhabitants, to lunar farming and experiments on a "critter colony," etc…

_ Expansion of the lunar population beyond contractors and technauts, to tourists and recruiting settlers who agree to live on the Moon for a year or more – this involves pre-departure and onsite training of families, and providing sufficient support services while aloft, and upon return to the home planet. (Refer back to chapter 6.)

H. H. Koelle, a respected German researcher at the Technical University of Berlin, has published on the subject, "Steps toward a Lunar Settlement." 40 As chairman of a lunar development subcommittee for the International Academy of Astronautics, he had access to some of the best global thinking on the topic as he built a lunar data bank, so his insights are significant. After presenting a compelling rationale and objectives, he examined three options for lunar transportation, recommending a single-stage-to-orbit tanker and a ferry from LEO to a spaceport on the Moon (SSTO). Dr. Koelle favors beginning with a lunar laboratory which over fifteen yeas would be developed into an outpost and refueling center. As this was enlarged into a permanent base and settlement, he envisions leasing space to commercial interests who would pursue development of lunar resources, from liquid oxygen and hydrogen to solar energy and astronomy. In a period of the next 50 years, he forecasts a lunar population of some 2,000 and a settlement that is 75% self-sufficient by year 2100.

As lunar dwellers and their infrastructures increase, our dispersal beyond Earth into our Solar System will gradually lead to the creation of a spacefaring civilization!

5. Conclusions on Lunar Developments

Flush with excitement of initial Space Age successes, Patrick Moore, British broadcaster and author, wrote a book in 1975 about *The Next Fifty Years in Space*. One Chapter was devoted to **The Lunar Base**, which he then forecasted would become operational between the years 1995 and 2000. With hindsight, one might ask why the U.S.A. did not follow up with plans for such an undertaking after the *Apollo* mission series ended? There were many political, economic, and social factors that prevented the nation from achieving such a vision by the end of the 20th century. Now space experts from NASA and the aerospace industry estimate that a lunar outpost might be functional by year 2020. From my viewpoint both as a management consultant and as a space psychologist, it would seem that **mindset** may prove to be the stumbling block, delaying and hindering the exploitation of space resources in general, and lunar resources in particular. To cultivate positive mindsets in both the world's political and space communities , as well as mass public support, here are some suggested activities to pursue:

- ***Place individual space missions in a larger context***—to think in terms of not just individual mission, but within the context of a broader strategic plan for lunar science and industrialization; emphasizing to the public near-term return on investment …

- ***FAct synergistically in global cooperation***—today no one country or space agency can effectively undertake space macroprojects without forming international partnerships; the sharing of talent and resources ensure long-term "paybacks" from space enterprises…
- ***Facilitate intersectoral and interdisciplinary planning*** —space macroprojects require going beyond traditional interfaces, such as public and private, science and business; investment will be forthcoming, for example, if goals include both science and industrialization, involving industry, universities, and entrepreneurs with government agencies in planning for a permanent lunar return.

The above review of current trends underscores why the next major **space** investment and undertaking by the U.S.A. and its spacefaring partners should the Moon, underscroing reimbursement to be realized for all of humanity, especially the home planet itself. Many "Mission to Planet Earth" goals can be achieved best by using the Moon as a platform for scientific, environmental, and economic advantage. The Moon can become the laboratory for international cooperation, the launching pad of humanity into the universe. Expert consensus for this is emerging as confirmed in this statement from an International Academy of Astronautics report: 41

We believe the time has come that these global trends should induce responsible governments to take action deciding to continue the development of lunar resources and consequently to assign an existing multinational space organization (or establish a new one) the responsibility of returning people to the Moon permanently and developing its resources for the benefit of mankind.

The author concurs in these recommendations, but is convinced that a "new multinational space organization" or regime must be formed to sustain joint lunar exploration, one that goes beyond but collaborates with existing national space agencies. To this end, we have proposed here the creation of **a** Lunar Economic Development Authority, and have explored several alternatives for accomplishing this goal. LEDA is considered a prototype for future space authorities that could be constituted to develop eventually other planets and asteroids in our solar system, as well as for constructing orbiting colonies as proposed by visionaries, such as the late Wernher von Braun and Gerard K. O'Neill. 42 This strategy offers a bridge over troubled waters in contemporary space policy and law, and a mechanism for constructing and really financing lunar infrastructure through public participation. This legal entity with its own Board of Directors enables national sovereignties to act synergistically in the exploration and development of the high frontier. It could not only issue revenue bonds for this purpose, but such a lunar development entity could literally build the "bridge between the two worlds of the "Earth/Moon system" by:

- Leasing land, facility, and equipment rights;
- Fund raising and fee collection from investors and developers;
- Site planning and permits for habitats & industrial parks;
- Zoning and inspection to protect lunar environmental and ecological concerns;
- Long-term management and peace-keeping within lunar settlements;
- Administering a lunar personnel deployment system, while regulating tourism.

Such practical matters have already been researched by Charles Lauer, when at the University of Michigan College of Architecture with reference to real estate aloft. He has written extensively on the financial, legal, regulatory, and design aspects of business parks in orbit that have implications for a lunar industrial park. 43 Now he is a founder of Rocketplane, Inc.

Yet another strategy for moving toward Industrialization of the Moon would be for the U.S. Administration and Congress to convoke a **White House Conference on Lunar Enterprise** that would build appropriate consensus, as well as lunar policy and strategic planning (see Epilogue). Another action would be for the United Nations to sponsor a global summit for the world community to consider a lunar development agenda, possibly under the aegis of the UN Office for Outer Space Affairs. Like previous convention sessions, this might be called **World Space Congress 2010.**

If such official leadership is not forthcoming, then transnational enterprise will act to fill the vacuum and promote space resource development and commercialization. 44 Since the beginning of the Space Age, the military of several countries have lusted for bases on the high ground, especially the Moon. Better to delimit their role to helping with space transportation, construction, and peacekeeping! The prophetic Krafft Ehricke envisioned lunar industrializaton as our **extraterrestrial imperative**, warning of the conse-quences with no-growth policies .

Obviously, pursuing lunar development is a growth policy for our world. Right now within the human family, there is much chaos and international destruction. How much better it would be for humanity to turn people outward and upward toward the stars in the space exploration and development! It might pull the international community together in common cause, and give youth hope for offworld participation! The high frontier opens up all kinds of future possibilities, as Exhibit 11illustrates.

EXHIBIT 11 * FUTURE POSSIBILITIES

PH

Future Possibilities – Humans offworld on other celestial bodies will engage in a variety of activities, some traditional and some never done before. An artistic rendering of "things to come." *Source:* NASA Headquarters

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The above essay, serialized in 5 parts, was specially prepared for ***Moon Miners Manifesto***.

The paper, in its entirety, will be posted at:
www.moonsociety.org/publications/papers/lunarenterprise.pdf

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Investing in Fuel Tank Infrastructure in the Architecture of Lunar Exploration

November 2008

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Background

At the **ICEUM*** 10 Conference Dr. Harrison Schmidt made a comment made about the NASA Altair Lunar Lander s having a proposed ascent system using hypergolic fuels. His concern was that reliance on a hypergolic fuels system would strategically preclude the subsequent use of in situ produced fuels such as liquid hydrogen and liquid oxygen. [* **I**nternational **C**onference on the **E**xploration and **U**tilization of the **M**oon]

The ability to produce in situ fuels is one of the major strategic objectives that will enable the scientific exploration and utilization of the Moon. Dr. Schmidt was reinforcing a view shared by many in the Space Resources Roundtable and the Moon Society that oxygen production should be one the highest strategic priorities of the technology development roadmap. The discovery of concentrated ice deposits in the polar cold traps would accelerate this possibility by refueling both hydrogen and oxygen tanks as well as storing water.

The technology roadmap currently involves a demonstration goal of producing 1 ton of in situ oxygen. (1) Few would argue against the proposition that one ought to crawl before one walks, but by the same token it is important to look strategically at the plans for use of landed assets, or the lack thereof, and try to eliminate roadblocks to more rapid utilization of in situ resources and of use of infrastructure for a variety of exploration, research, and commercial purposes.

The strategic roles of tank infrastructure NASA's Tank Contribution The NASA's Vision for Space Exploration has resulted in a lunar exploration architecture that results in three Ares V missions to the Moon per year beginning in 2020 in the build up of a lunar outpost. (2)

Each Altair lander descent system will leave 4 oxygen and 4 hydrogen tanks on the lunar surface with a capacity of 27 tons. Thus, each year, 12 oxygen and 12 hydrogen tanks with a combined capacity of 81 tons are delivered to the surface. Between 2020 and 2025 some 18 landers will be left at the lunar outpost with a total tank capacity of 1,458 tons. (3)

ESA Tank Contribution NASA has also been coordinating the development of its Constellation architecture with ESA so that there can be a complimentary effort. ESA is now studying development of a lunar cargo lander, based on the commercial Ariane V launcher, with the capability to deliver 1.2 tons to the lunar surface. Such ESA cargo landers will presumably also deliver a significant set of oxygen and hydrogen tanks to the lunar surface.

The other spacefaring members of ILEWG: CNSA, ISRO, JAXA, ROSCOSMOS, will similarly deliver tanks to the lunar surface with their landers. One hopes that similar efforts to coordinate the development of the lunar exploration architecture of these agencies in a mutually advantageous manner can occur as ISRO, JAXA, ROSCOSMOS, and CNSA etc. lay out their technology development roadmaps.

Valuing Tank Infrastucture

The value of these tanks is their necessity in getting to the lunar surface in the first place. Secondary utilization of these tank has great strategic importance. These empty tanks are potential beginning elements of commercial, industrial, and research infrastructure on the lunar surface. Potential uses include:

The fuel tanks, if refueled could potentially enable the reuse of an Altair vehicle. The capacity to refuel and reuse an Altair could enable sortie missions across the lunar globe. A number of such vehicles would also make for a redundant capacity for exploration or rescue of human crews on extended treks if needed.

The tanks if refueled can provide a "back-up" source for life support gases for habitation at the lunar outpost. These tanks could provide an operational reserve for crews whose life support systems failed or where some catastrophic accident has occurred with primary supplies. This reserve could buy the crew the time needed for a rescue attempt.

The tanks if refilled might provide refueling of other vehicles as a "lunar gas station." This fuel capacity serving all space faring nations involved in landing at a lunar outpost could provide the beginning of commercial activities on the Moon.

ILEWG could develop a collaborative model of the lunar supply chain to the lunar outpost involving all of the launchers and landers of its members. A whole systems model of fuel demands and of fuel storage on the lunr surface might be developed. This model could then "inform" the design of common service and support facilities.

A "**Lunar Port Authority**" could serve as the purchasing agent and thus acquire its "tank farm" from national space agency transportation providers. A Lunar Economic Development Authority (LEDA) could be a target of private investment capital in the creation of servicing facilities that facilitate both national missions and private lunar activities such as lunar tourism or commercial research. This type of model would allow a LEDA to create habitation facilities, and private laboratory facilities utilizing the BA330 units being designed by Bigelow Aerospace or possibly lab modules already flown on the shuttle by SpaceHAB, as well as tank farms and refueling facilities.

These considerations would be a proper issue for ILEWG to discuss as a matter of developing inter-operability standards and hardware for gas exchange systems and tank farm infrastructure. The tanks might be used for storage of other in situ volatiles that would result from an end-to-end demonstration of processing in situ materials.

The designation of the ISS as a national lab facility by the US provides a powerful precedent for the creation of dedicated laboratory facilities at a lunar outpost. It would be logical to expect nations with human lunar programs to extend their program by adding research facilities just as has happened with both ESA and JAXA on the ISS. Tanks that have been used as part of a transportation architecture might also with modification do secondary duty in curation of lunar samples. They might provide a mechanism for transport of lunar samples (when fully purged) preserving the vacuum environment on return to Earth or as elements of a curation system storing lunar samples brought back to the lunar outpost in a sealed "protective" container to maintain their pristine condition in a curation environment on the lunar surface.

These tanks could be sold to the LEDA authority or another commercial entity thus recapturing a significant share of the capital invested in the transportation services. This secondary market for the tanks could therefore reduce the cost of transportation services. It also provides "price points" for those wanting to model the cost of acquiring lunar infrastructure and of the investment requirements of a lunar surface market.

There are no doubt other uses that can be suggested for these tanks. Dr. Schmidt's concern's only underscores the importance of taking these varied considerations in mind in the beginning engineering design of the tanks themselves and of identifying the secondary markets for these tanks.

No More Missed Opportunities for Commercialization

There were many suggestions over the years for the use of Space Shuttle tanks in LEO but no action was taken by NASA perhaps because no credible near term market existed for their use. Perhaps it is easier to envision many secondary uses for these tanks on the lunar surface in conjunction with growth of a lunar outpost. These secondary uses would represent the next enabling stages of the evolution of a lunar outpost into a lunar base.

Groups such as the Space Resources Roundtable, and LEAG, should consider the needs of the in situ resource research community for tankage as part of defining a laboratory facility capability for in situ research and demonstration. This definition should also information NASA's commercialization initiative and the need to develop both contractual and legal frameworks for secondary tank utilization. The design and engi-neering work of the Altair should "set up" the infra-structure of secondary utilization.

The same recommendation is made for ESA lunar cargo lander and the other members of ILEWG and OSEWG that are landing on the lunar surface. (1) (2) (3)

<DD>

PARADIGM SHIFT

Editorial Commentary on the Article Above

By Peter Kokh

We wholeheartedly endorse the proposal of David Dunlop that fuel tanks on the proposed Altair Lunar Lander, and all other craft being designed to land on the Moon, be designed for reuse on the Moon.

We have, in fact, called for the design of *all lander compo*nents not returning to space, to be pre-designed to serve other "post-consumption" needs on the Moon. See our article "Thinking Outside the Mass Fraction Box, I" in MMM #209, October 2007, page 3.

http://www.lunar-reclamation.org/papers/mass-fraction-box.html

We also touched on this design mandate in our series, "The Outpost Trap," particularly in Part I, MMM #198, September 2006. This series is now online:

www.lunar-reclamation.org/papers/outpost_trap.html

Dave has shown his paper to a number of notables inside and outside of NASA with very mixed results. Those coming from industry in general had a positive reaction, those from NASA, nothing but criticism. That's to be expected.

The problem is that NASA's eyes are focused on its narrowly defined mandate: to place an occupiable camp site (not an occupied moon base) on the Moon. Any money, however trivial, spent on tweaking a component's design so that it has some future use in a scenario of expanded operations cannot be considered.

Of "ladders and rungs": a lesson from ISS

This kind of thinking, looking at each "rung" in a ladder as an end in itself risks creation of a "rung-like" entity that does not lead to a next "rung." Witness the International Space Station, put by political compromise in a high inclination orbit that precludes its usefulness as a depot or staging point for deep space missions. The Station's only use is for Earth Observation. ISS is the pride and joy of "yo-yo space" or reflexive space or intransitive space. That is not to downplay its usefulness as such. But those of us who lobbied long and hard to realize von Braun's "stepping stone to space," got something quite different than what we wanted.

NASA mission planning and architecture is the miscreant pride and joy of a budget process that is incapable of looking forward. And those of us who waste our time lobbying Congress to do this and that do just that, "waste time."

The need for a "Paradigm Shift"

We need a paradigm shift, one designed to keep the ladder in mind, tasked with designing every rung to be pregnant with the next rung, and on and on. To get that shift, we have to widen the list of players. NASA and the US Government are useful, but cannot alone deliver, and must not even be allowed to play "the" anchor tenant role.

Thinking beyond NASA

We need to bring into play the space agencies of other nations: ESA, Russia, China, India, Japan, and others not yet at the table. But we also need to bring industry and enterprise, not just as "under contract" but as contractors and service providers, who will someday build their own facilities on the Moon to serve the various international agencies, enterprises such as tourism, mining operations, science installations, and more yet unforeseen.

Once we are talking cooperation between a number of agencies, a number of contractors, and a number of service providers, the logic of cheating the "Mass Fraction" limit on launched payloads, by designing every component needed for the journey *to* the Moon, for an after-life service *on* the Moon. That way, the "landed payload mass" includes not just habitat and needed equipment, but every last bit of the non-returning lander consist - tanks, struts, winches, plat-forms, legs, pads, ladders, cargo holds, and so on.

A lesson from poverty

Among the poor, the culture of using *everything,* and wasting *nothing,* is well known. In cooking a pig, one uses "everything, but the squeal!" Because building and expanding operations on the Moon will always be more, much more, expensive than similar operations on Earth, we must adopt the same philosophy, of "using everything but the squeal." *Every item we can reuse is an item we do not have to pay to ship from Earth.* Its freight was paid for in the shipping charges for the cargo per se.

"Making every step pregnant with the next" will lead to a timely, "inflationary" expansion at an ever accelerating rate. For NASA to create an induarial settlement on the Moon, one self-limited step at a time, could take centuries. If we shift the paradigm, we could have the start of a settlement within a decade of our first crewed return to the Moon. This will be inconceivable to those whose minds have become imprisoned in NASA-Congressional-Budget-Process-culture.

The Paradigm must shift not only as to what we define as "landed payload" on the Moon, but as to the current dismissal of the benefits of "leveraging" that come from refueling along the way and taking anything that could conceivably be reused to the next platform level: LEO, GEO, L1, LLO etc.

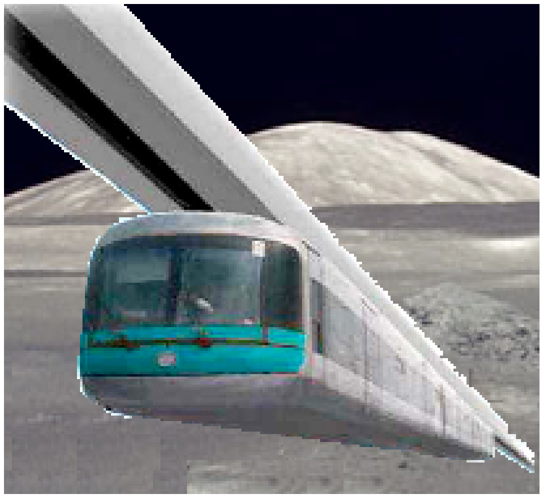
NASA dismisses "refueling" and "fuel depots" as inefficient. Yes, if you are only looking a one mission, or a very limited series of missions, rather than an every growing and evolving "inflationary" build-out of operations on the Moon. Change the goal, and the equation changes with it. If NASA will not or cannot change its concept of the goal (each rung as an end in itself, not necessarily leading to another rung), then NASA must be demoted as "the player" to the status of "a player."

The Moon Society's role

At the top of our homepage there is a declaration that we were "formed to further the creation of communities on the Moon involving large-scale industrialization and private enterprise. Following the link, we are pledged to complement "NASA initiatives and goals by looking for alternative options to advance research goals NASA is no longer able to undertake." Not all of our members are aboard yet, but our role is clear. <**PK**>

Elevating Lunar Railways Above the Surface

By Christopher D. Carson



I have read with interest the discussion of lunar railroads published in recent MMM issues and on the Google Group: Railroading on the Moon and Mars.

http://groups.google.com/group/railroading-on-the-moon-and-mars?hl=en

The idea that, at some stage of lunar settlement, a high-capacity means of transportation for personnel, goods, and raw materials between sites on the lunar surface will become desirable appears a sound one; nevertheless, the significant differences between terres-trial and lunar conditions perhaps make it desirable to deviate from established terrestrial practice more than your contributors have generally proposed.

In particular, I would suggest that some form of elevated carriageway is desirable. Firstly, the lunar surface is very uneven, and that unevenness is distributed very differently from the unevenness of the terrestrial surface, having been (in the main) produced by very different processes.

Considering the low lunar gravity, which increases the allowable unsupported span length, the operational problem of erecting a suitable support structure which is only in contact with the ground at intervals may well be less than that of grading and blasting hundreds of kilometers of right-of-way across cratered terrain.

[Ed. for passengers and tourists, elevated systems will provide a better view, over a more pristine landscape.]

Advantages: dust control and thermal management

Secondly, elevating the carriageway introduces at least two major advantages, with respect to dust and to thermal management. The lunar surface is dusty, and a passing train can be expected both to disturb the existing surface dust by its vibrations and to generate new dust by mechanical breakdown of the ballast. This dust will tend to foul rotational joints such as wheel bearings. As the rate of dust collection on a surface can be expected to decrease rapidly as that surface is elevated above ground level, and no definite requirement for a ballasted roadbed appears in an elevated system, this problem can be reduced significantly. Again, although the soil is a relatively good thermal insulator, a ballasted rail system laid across the surface will tend to approach the surface temperature.

The diurnal variation in temperature, especially in low latitudes, is large in comparison to terrestrial norms, and issues related to thermal expansion (already significant in terrestrial experience) are correspondingly magnified. Conductive heat transfer can probably be limited to a much smaller value in an elevated system than in a ground-level system, and if the surfaces of the carriageway are mostly metallic (polished where possible), their low emissivity will limit radiative transfer as well. The use of electrical heating at night, and passive or thermoelectric-assisted radiative cooling during the day, will permit maintaining the carriageway close to a constant temperature without impairing its mechanical properties (unlike keeping it heated constantly to its peak daytime temperature).

There are two general arrangements that are especially suitable to elevation, namely the monorail and the cableway. Either would permit high angles of bank, as required for stability in sharp turns under low gravity. The underslung monorail, having pendulum stability, is arguably preferable to the superincum-bent type but either can exhibit more lateral stability than the ordinary railway, if con-structed with the wheels or rollers necessary to apply moment reactions against a rail in the form e.g. of a box girder.

Of course, under lunar gravity the permissible column length will be extended considerably, so that an elevated carriageway will not need to follow the terrain elevation as closely as a surface carriageway, and curves can in general be made much shallower. While a lunar cableway can probably be built for much heavier traffic than its terrestrial counterparts usually see, it will tend to have greater frictional losses than a rail system (due to the cable working against wheels or skids at each support), and the cable will require frequent inspection and renewal against the danger of abrasion by trapped dust grains. For most purposes, therefore, the monorail will probably prove superior.

Powering the system

As an alternative to the usual mechanical type of railway, the magnetic-levitation carriageway also deserves consideration. In particular, the "passive" maglev guideway, which need be little more than an aluminum trough, would be relatively simple to fabricate and install. This throws the burden of support and propulsion upon the train, but the one can be provided using rare-earth magnets in the car structure, and the other by a linear induction motor, probably in the foremost (for driving) and rearmost (for braking) cars, although in practice all cars would probably be motor-equipped to ease the problems of train assembly.

As with all forms of lunar transport, power will have to be supplied either internally, from batteries or some form of generator, or externally from a feed. The external supply in all cases may be a cable energized with single-phase alternating current and tapped by pantograph, although the return will largely be by way of the rail rather than the ground as in terrestrial applications. (Capacitive coupling between the car and the guideway makes this possible for the maglev.) For the maglev, as frictional losses are small, propulsion is ordinarily required only intermittently, which in principle would permit power pickups (fed, perhaps, by spot beams from a power satellite) to be located at intervals, eliminating the need for a continuous cable. Safety and other considerations, however, probably render this a questionable economy.

In general, human nature remains the same, and the generic problems of living are the same in Luna as in Terra ; but by as much as conditions differ on the two planets, so much will our solutions need to differ. Keeping sight of these principles, if we apply imagination and good engineering sense, we should be able, not only to survive, but to thrive.

Christopher D. Carson
http://www.lunarcc.org/

Lunar Railways: Surface & Elevated

By Peter Kokh

In the above article, Chris Carson lays out a number of considerations that arguably favor an elevated approach to lunar railways. But he himself says that he is looking at "some (future) stage of lunar settlement, (when) a high-capacity means of transportation for personnel, goods, and raw materials between sites on the lunar surface will become desirable."

Lunar Railroads not as a later development, but as an early means of settlement expansion

David Dunlop and I, believe that railroads should be part and parcel of lunar settlement expansion from day one. If there is a central spaceport feeding a growing beachhead of habitation, commerce, and industry, a rail system will be the easiest way to move heavy modules around. The chosen location, unless we are insane, is likely to be a level one *(oops! I guess that leaves out the Shakeleton rim!)* and laying rail beds should be fairly straightforward.

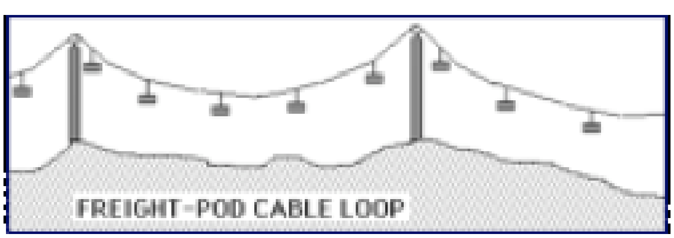
If our initial site is in a lunar mare basaltic plain, expansion to new settlement locations by rail will be easy as well. There are, of course, some mare features that pose problems: wrinkle ridges and rilles. The forme will need to be cut or tunneled through, the latter to be bridged or detoured altogether. But in general the near-side mare-plex is relatively flat. Elevation changes are of low grade.

Beyond the Flats

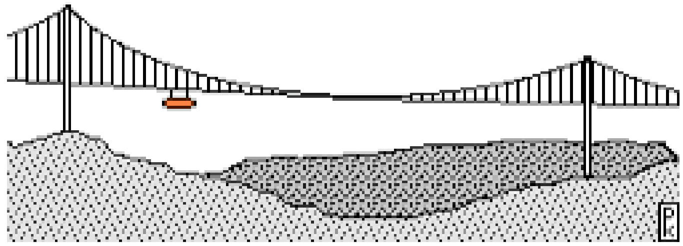
Where railroad routing will pose a challenge is in the cratered highlands. I say "pose a challenge" because mid-nineteenth century railroad engineers managed to conquer the Rockies and, in Europe, the Alps.

Still, there are clearly cases where elevated rail systems are more desirable, for example through very scenic and geologically special terrain that we will want to disturb as little as possible.

In situations like this, especially with railways designed principally to cater to the tourist trade, elevated monorail systems may not be the initial choice. Cableways, with cars descending and rising between the cable towers might be less expensive to build.



As population and tourist traffic grows, a suspension cable systems in which cars ride a horizontal cable suspended from a tower hung cable much like the roadway of as suspension bridge, might be a welcome upgrade even though it would be more expensive, requiring more steel.



Rights of Way: expensive on Earth, free on the Moon

Elevated monorails and maglevs, as opposed to cableways, will be built when high speed passenger traffic grows in volume. Today, these systems are still too expensive, because they need all new road beds and rights of way, which tilts economic decisions in favor of high speed trains on traditional tracks along established rights of way. On the Moon, securing new rights of way will not be a problem, and decisions will be made on other grounds.

Terrain stability and "moonquakes"

Another consideration may come into play: one thing that we did not realize until sometime after the Apollo period is that some areas of the lunar surface are subjedt to "moonquakes." These events are analogous but different from "earthquakes." On the Moon, quake epicenters lie very much deeper below the surface, and the quake lasts not seconds, not just a few minutes but for periods as long as an hour or more. While on the Richter scale, these events are of mid-range, c. 5.0 at most, the damage that they can cause because of the duration, could be very serious. Now we don't really know. On Earth, the greatest damage is where the ground is soft, wet, or fluid in the first place. On the Moon, the surface is compacted regolith over fractured bedrock almost everywhere. We will be learning some hard lessons from experience.

While on Earth, quakes are caused by the build-up of tectonic stress, on the Moon, where there is no such thing as plate tectonics, the cause seems to be in instabilities very deep inside the Moon.

Now to our present knowledge these quakes are much more common in some areas than in others. In many areas, concrete maglev roadbeds suspended on pylons may have an indefinite problem-free lifetime. In other areas, surface systems may be more prudent.

Expansion / contraction with heat / cold

Chris brings up the problem of thermal expansion and contraction of rails exposed to the lunar heavens. This is a problem that we recognized early on in our 1993 paper, "Railroading on the Moon."

http://www.moonsociety.org/publications/mmm_papers/rr_moon.htm In this paper we discussed various ways of shielding the rails from direct sunlight:

- Putting them underground, in tunnels.
- Using a suspension system that allows the trucks or bogies to ride on rails in a shaded box,
- Putting each rail in a box covered with shutters that swing aside just in time, and
- Suspending cars from an inverted box beam supported by pylons, much as Carson suggests. **PK**

"Moon or Mars" is the Enemy of Both

Guest Editorial

By Shaun Moss, Melbourne, Victoria, Australia

Both the Moon and Mars have important advan-ages, which i why I've always advocated colonization of both. They both far surpass any other known destinations followed by Earth orbit, NEA's, Mars's moons, Mars orbit and the main asteroid belt.)

The Moon

- The Moon has abundant natural resources that can improve the quality of life on Earth, including helium- 3 (fusion energy), and engineering metals such as titanium, aluminium and magnesium (spacecraft, computer and robotics components).
- It's one of the most interesting destinations in the entire Solar System scientifically, since informa-tion about the formation of the Solar System is betterpreserved on the Moon than any other location.
- It's an arena of activity that can unite the people of Earth, being a highly visible and beautiful shared resource. The Moon is the future international space **station.**
- Due to its low gravity well, the Moon is an excellent launch pad for robotic and crewed exploration of the Solar System.
- The far side is an excellent location for both optical and radio astronomy, e.g. searching for extrasolar terrestrial planets/extraterrestrial intelligence, being shielded from the radio noise of Earth. The VLBI and OLBI telescopes we can and will build on the lunar far side will utterly dwarf the capabilities of Hubble, Kepler or any other orbital telescope.
- It is an excellent tourist destination, being relatively close to Earth and having the potential for many fun low-g sports, plus the Solar System's best view of Earth.
- Being close to the Sun and not having an atmosphere or magnetosphere, it provides one of the best ground-based locations in the Solar System for solar energy production, second only to Mercury.
- Being also cold, dry and dusty, the Moon is a suitable location for testing Mars exploration and colonization technologies before transporting them to Mars.

I find it astonishing that anyone could consider that we have "been there and done that" with regards to the Moon. The Moon has a surface area equal to Africa and Australia together (30.93+/-.01 million km2). If 12 people visited various locations in Africa and Australia, would we think that we had seen all of both? Or that Africa and Australia had nothing left to teach us?

Do people really think the Moon is that dull? I think people forget that humans are smaller than microbes on ants when compared to planetary bodies. I will bet you stars to asteroids that in 1000 years, when the lunar population is in its millions, we will still be learning things from and about the Moon.

Mars

- Mars is expected to have undergone much the same types of geological processes as Earth, thus it is expected that concentrated deposits of metals can be found there using similar techniques and technologies. Furthermore, these can be discovered and accessed more easily due to the absence of trees, oceans, and human settlements. Metal is wealth.
- Mars has all the elements necessary for DNA-based life and may indeed currently harbor DNA-based organisms (e.g. methanogenic chemotropic cryohalophiles).
- Mars is comparatively close to Earth (only the Moon, Venus and NEA's are closer).
- Mars has a diurnal cycle of 24 hours and 40 minutes, almost exactly equal to Earth's, which means that Earthly organisms, including humans, should be able to adapt relatively easily to Mars.
- Mars has an axial tilt almost equal to Earth's, which, combined with the presence of water, results in familiar patterns of seasons, climate, clouds and weather. These will also help many Earthly organisms to adapt.
- Mars is the only Solar System body other than Earth with a tangible yet translucent atmosphere (i.e. you can see the planetary surface from space).
- Mars's similarity to Earth captures human imagination, having a colorful sky, clouds, weather, fascinating geological formations and excellent views. It is easier to imagine (and actually build) human settlements on Mars than any known extraterrestrial world.
- Mars has more potential as a second home for humanity than any other known astronomical body. Colonizing a 2nd planet is essential for the guaranteed long-term survival of the human species because ELE-scale asteroid impacts, while infrequent, do happen.
- Mars is an excellent location from which to launch an asteroid mining industry, being closer to the majority of the Solar System's asteroids and having a much lower gravity well.
- Mars is also an awesome tourist destination, offering endless possibilities for hiking, climbing, exploration and low-g sports.
- It is widely believed that Mars can be terraformed, or in other words, engineered to support an uncontained biosphere. This means Mars may eventually support ecosystems that grow and evolve with no or minimal technological assistance. Mars may therefore eventually support billions of humans and other organisms. We know of no other extraterrestrial world with that kind of potential.
- Mars is a place where we can create a largely legacyfree society, without all the corruption, baggage and ugliness of Earth culture. On Mars we can introduce the very best economic, political and environmental strategies, beginning, as we can, with a whole-planet perspective.

Given that both the Moon and Mars are highly desirable targets, why bicker constantly about which deserves more attention? Send humans to the Moon first to test technologies for Mars, then send them to Mars. Then develop both in parallel, while supporting private enterprise as much as possible so that the expansion becomes economi-ally feasible and self-sustaining. The result will be nothing less than world peace on 3 worlds. **SM**

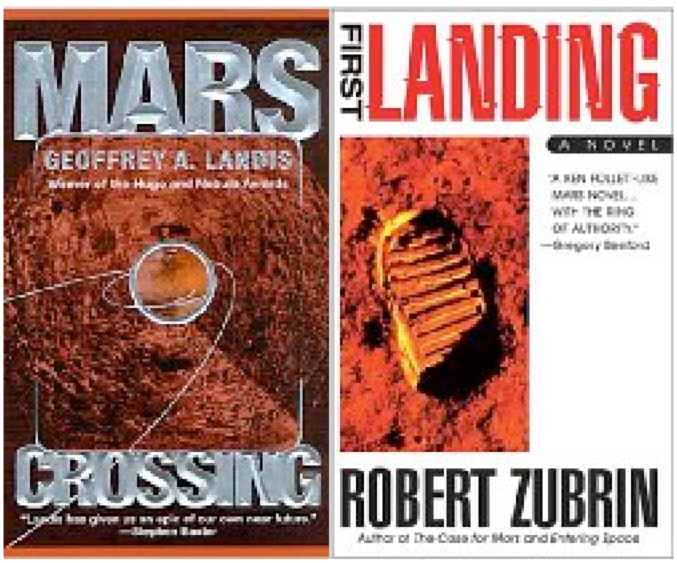
"Mars: The Audacity to Stay"

By Peter Kokh kokhmmm@aol.com

> "All the scenarios currently being floated aim at a one-time scientific orgasm of activity -- and then we come home, probably never to return, once the public thrill with early results begins to wear thin.
>
> *"It goes without saying that all these people doing the careful planning will want to return to set up a permanent base. But once it finally sinks into the mass consciousness that even Antarctica is a friendlier place, political support will vanish and funding will disappear, unless ...*
>
> "Unless we plan the very first Mars expedition with a built-in OPTION TO STAY."
>
> - From "Mars: Option to Stay," by Peter Kokh, MMM #19, October 1988, pp. 3-5

It is now 20 plus years later, and nothing in the prospects cited above has changed, including the blindness of most Mars activists who think an Apollo-like Mars program will actually lead somewhere other than to the dusty pages of old history books.

However, in the meantime three other voices in favor of a revolutionary bold "let's just do it (settle Mars) approach have joined in. First was **Geoffrey A. Landis** in his 2001 novel **Mars Crossing**; then **Bob Zubrin** himself in his 2002 novel **First Landing**.



In both these novels, some of the first explorers end up refusing to return to Earth

Now Buzz Aldrin has made a strong statement in favor of the only decision that makes long-term sense.

http://www.universetoday.com/2008/10/23/aldrin-mars-pioneers-should-not-return-to-earth/

"The first explorers of the Red Planet should stay there. Following similar lines of the first European pioneers who settled in America, a small group of interplanetary explorers should expect to land, build, live and retire (probably even die) on Mars."

{Quote from the article, not necessarily Buzz Aldrin's exact words.)

Obviously, this is not the usual cautious "toe in the water" approach of NASA, and talk like this must either horrify the agency or be dismissed with ridicule. But anyone who thinks that while it failed on the Moon, a "Flags and Footprints" approach to Mars will really lead somewhere, is the fool, not Aldrin, not Zubrin, not Landis, and going back two decades, not this writer.

Rationale for the one step at a time approach

The standard approach allows us to

(1) Concentrate on transportation technology, and

(2) Give minimum attention to the much more demanding requirements

- (a) Long-term life support,
- (b) Outpost agriculture and food production
- (c) Processing local soils to produce local building and manufacturing materials.

We've said many times that "the rocket scientists can get us there, but it will take a lot of other expertise to allow us to stay, and frankly, those needs are not NASA's area of expertise.

But we can't really fault the agency. What the agency is, and its in-house talents are a reflection of the vision, or lack of it, of US Administrations and Congress. Given that, is it realistic to believe even for a moment that some other approach is possible? No!

That is, it is not realistic *unless we stop* pinning all our hopes and dreams on the shallow intelligence and timid vision of elected politicians.

Yes, in the past, the establishment of some frontiers was a national policy of some nations. Yet other frontiers were established by mass movements of many individuals who were motivated to take things into their own hands in an effort to find and establish a better world for themselves and their families.

We've said it before: Those who were doing well-enough in Europe stayed there. It was those with talent and drive and ambition, but with little opportunity to advance "at home" who left to found and develop new frontiers. The same thing is true in the animal kingdom. Males frozen out of leadership moved out to claim new turf. And the process continues. In the 1800s, those who were comfortable in Boston and Baltimore (nothing personal!) stayed there. Others with talent but finding all positions at the top taken, settled the west.

I've called this the 11th Beatitude:

"*Blessed are the second best!"*

The point is clear, establishing new frontiers is something that the people who would do so, must take ownership of, counting only on themselves. If they can get governments to help them "partway" all the better.

Establishment of a Mars frontier, one on the Moon too, may have to be by revolt: refusal to return home. Of course, agencies will try to weed out candidates suspected of harboring such nonsense attitudes. But it will happen anyway. And that is what I loved about Bob Zubrin's novel especially. Two people took the leap and made the decision to stay behind, no matter how great the odds were that their effort would fail and they would die a lonely and premature death, *"for nothing!"*

It's all about preparation

Clearly, any group intending to stay behind on Mars and actually survive and thrive, must, in concert with sympathizers and supporters on Earth with no intention to join the movement themselves, must do a lot of preparation! This will include robotic exploration, getting NASA, ESA, ISRO, JAXA, Roscosmos, and China to send probes that will:

(1) Thoroughly map all the key resources of Mars at very high resolution
(2) Produce an altimetry map of high resolution both vertically and horizontally
(3) Map unseen water reserves
(4) Explore known lavatube entrances

These are all things of great interest to scientists who only want to understand Mars, and who could care less about Mars ever becoming a second homeworld for humans. It is thus reasonable to believe that we could get this part of the needed homework done for us, by the established space agencies and space-faring nations.

Learning to use Mars' resources

Now comes the hard part. This is the sort of stuff NASA talks about for the Moon, but won't do anything about, because it is not part of the Agency's current mandate, We who want to go or who want to make it possible for others to go, need to see to it that this kind of research gets done.

Atmosphere mining

Thanks to Bob Zubrin, we know how to produce methane, for use as rocket fuel, from the Martian atmos-phere. But if we are going to stay, we need to be able to mine the carbon, oxygen, and nitrogen rich atmosphere to produce many more substances than methane.

Propane is another useful fuel, and a step up from methane. Ethylene is a feedstock for plastics. Atmosphere mining can be the basis of a Martian equivalent of our terrestrial petrochemicals industry. Oil, of course, includes a greater list of elements to start with, as does coal. The point is that Mars air is a resource lacking on the Moon, and any prospective settlers who go to Mars unprepared to hit the ground running with a developed atmosphere mining byproducts industry deserves to fail.

We need to know not only what we can make out of Mars Air, but also how we can do so. That means experimentation in the lab, and verification with production-type processing demonstrations.

Building Materials - non-metallic

We should have no trouble finding raw material suitable for making ceramics, glass and glass fibers, and glass composites, as well as concrete. What we do not know at present is where the best feedstock material for each of the above is to be found. And if it is not to be found in the form upon which we base our terrestrial industries, we need to experimentation to find alternate paths, and develop those to the point where we can design production plants ready to start turning out product one they arrive on Mars.

Our concrete industry is based on limestone, calcium carbonate, layers of which are made from fossil seashells. We would be astounded and flabbergasted to find such handy deposit on Mars - there are none on the Moon - so we have to be ready to make cement from other sources of calcium and carbon.

Building Materials - metallic

Mars should be abundantly endowed with the four principal engineering metals: iron, aluminum, magnesium, and titanium, as is the Moon's crust and regolith blanket of pulverized rock powder. But in contrast with the Moon, Mars may have reasonably abundant copper and other strategic alloying materials in which the Moon seems to be deficient. We need to determine before our arrival where the richest or most workable deposits of each are to be found. And if the metal-bearing ores are different from those we rely on here, then *we must predevelop the processes and the equipment* to produce these metals on Mars.

Building materials - organic

We will find no forests of any kind on Mars, but there is no reason that we cannot plant them in suitably pressurized greenhouses. We will want to concentrate on fast-growing species like bamboo and cottonwood.
http://www.fast-growing-trees.com/FastestTrees.htm

We are currently exploring many new ways to use bamboo, and we could do the same with other very gast growing trees.

We could experiment with all sorts of waste biomass products. This is something that would not be suitable on the Moon, where the constitutive elements of carbon, hydrogen, and nitrogen are so rare that we will need to plow all waste biomass back into the biosphere.

On Mars we can afford to splurge. That said, the Martian settlers would have to be careful. When we have a fire we can open a window and let out the smoke, on Mars as on the Moon, opening a window will not be an option, so we cannot "allow" fires to happen in the first place, and that will mean many strict protocols on how we use and store combustible organic products.

Who is working on what?

The Mars Society seems to be concentrating on pushing a series of manned exploratory missions, and not at all concerned with how we might set ourselves up to stay. On the other hand, the spin-off **Mars Homestead Project™** of the **Mars Foundation™** is doing just that. So if you support the "Mars to Stay" vision you may want to support this group. - http://www.marshome.org/

Mars Homestead Project Research Goals

http://www.marshome.org/research.php

1. Create a unified planning document with requirements for the first permanent settlement on Mars.
   - Identify core facility, mining, manufacturing, agricultural, and other technologies needed.
   - Determine how relevant terrestrial research can be conducted to advance these technologies.
   - Determine schedules for terrestrial research
2. Conduct research into core technologies and methodologies with terrestrial facilities
   - Determine best methods to utilize materials & resources on Mars
   - Create prototype terrestrial-based hardware to demonstrate utilization techniques
   - Build analog terrestrial facilities to finalize Mars settlement-building techniques and test operations
3. Establish key commercial and financial interests to support a Mars settlement.
   - Emphasis is placed on Mars resource utilization and manufacturing to reduce transportation requirements and cost.
   - Partner with other organizations (commercial & non-profit) whose goals align with permanent settlement design.
   - Develop a framework for coordinating activities that are in the common interest of perspective private, commercial, and public involved parties.
4. Generate a detailed plan for launching & building the settlement on Mars

- Not tied to specific hardware
- Determine methods to deliver cargo and crew for an initial permanent settlement of 12 crewmembers.
- Settlement would possess an integrated manufacturing capability
- Settlement would possess capability to seed other settlements

5. Assist with the exploration of Mars with a focus on permanent settlement enablers
   - Survey Mars for underground water & mineral sources
   - Gather data to determine adequate locations of permanent settlements

Analysis of the Mars Homestead Project effort

I am not sue that an initial complement of twelve is quite a "critical mass" – two or three times that number would be a more promising start – but in general the Mars Homestead Project™ is on the right track and I have personally lent my support.

Some, certainly not all, of their research will apply to our efforts to open a real civilian industrial frontier on the Moon as well, and sooner, not later.

There are many, perhaps an overwhelming majority ready to concede that a long period of cautious exploration will come first. And that is the hurdle we face. Perhaps the majority of Moon and Mars frontier supporters are overly conservative, won over by the "Oh, we can't do that!" experts. It is the can-do people to which we must listen. That is not the same as ignoring the obstacles and difficulties and hurdles of all kinds. It is about finding ways to surmount them and do it anyway.

"First tell me all the reasons why "this" can't be done. Then tell me how we are going to do it anyway!"

Excerpts from Mars: Option to Stay

(article cited at the beginning of this essay);

"All the scenarios currently being floated aim at a one-time scientific orgasm of activity -- and then we come home, probably never to return, once the public thrill with early results begins to wear thin. *It goes without saying that all these people doing the careful planning will want to return to set up a permanent base. But once it finally sinks into the mass consciousness that even Antarctica is a friendlier place, political support will vanish and funding will vanish, unless ...*

"Unless we plan the very first Mars expedition with a built-in OPTION TO STAY."

A Complete Phobos Base:

A forward base on Phobos or Deimos could be critical for the success of the effort.

• A Phobos Base could earn its keep by processing regolith volatiles (carbon, hydrogen, and nitrogen) in the form of methane (CH_4) and ammonia (NH_3) for back-shipment to thirsty Luna, as well as for fuels for actual Mars landings, and for return trips to Earth. Note: at this time we are not sure that either Phobos or Deimos are endowed with such volatiles as would be the case if these moons were of the Carbonaceous Chondrite family. The upcoming Russian ***Phobos-Grunt*** mission, could answer this question.

• Final preparatory Mars telescience from this forward position. A separate Mars-synchronous station could best direct the tele-explortion and tele-prepartion of a selected site, and

• Oversee the carefully plotted siting of parachute-landed robotic production plants on the Martian surface to stockpile nitrogen, oxygen, argon, carbon monoxide, water, methane, and ammonia -- all processed from the atmosphere -- [written *prior to Mars Direct*]

A Phobos Base would vastly enhance chances of success for a crewed Mars surface mission as well as assist the economic bootstrapping of the early Moon Settlement so that it could manufacture and ship some items ... at considerably less expense than they could be sourced from Earth.

Launch Window circumventing Solar Sails

A steady stream of *"tackliners"* – container pods hauled by great solar sail frighters, with some measure of freedom from launch windows, could build up caches of supplies in Mars orbit to be on hand when the sprinting human crews arrive, or to be fetched by shuttle when needed by crews already on Mars surface.

One very big "However ...!"

I Those who would open a lunar frontier, while being less blessed with mineral resources than pioneers on Mars, will have the enormous advantage of "location, location, location" which will allow the Moon to become an integral part of an expanded terrestrial "Econosphere" allowing pioneers to earn their keep producing products and services that will help those on Earth ameliorate their two inter-twined critical energy supply and environmental degradation problems.

That its all about mineral "resources" is not quite so. Japan lacks key resources. But its people had something more essential: *resourcefulness, inventiveness, and ingenuity.* The Moon could become the Japan of Space.

In contrast, the economic case for Mars has yet to be written. This was the topic of our presentation at the 1994 ISDC in Toronto, and little has changed that outlook since. Worse, very few Mars enthusiasts are paying any attention to this problem.

True, Mars has what it takes to be self-sufficient. *But to get to that state,* it must rely heavily on imports, and to keep those imports coming, it must develop products and services to sell. Touting Mars eventual self-sufficiency is clearly "playing ostrich."

It is in everyone's interest, Moon and Mars advocates alike, to try to develop the Economic Case for Mars, without resort to science-fictional discoveries of unobtanium, or priceless pharmaceuticals developed from Martian microbes etc.

In this essay, we have tried to show how we could go to Mars to stay. But *to really make it work, we need to do a lot of economic homework so far being pushed aside and ignored.*

This is in the interest of Moon-settlement advocates as well. Products and materials from Mars and especially from Phobos and Deimos would be much cheaper in terms of shipping costs than equivalent items shipped up the steep gravity well from Earth. In our estimation, the Moon and Mars will both have a better chance of economic survival as trading partners than either frontier would have in a future in which only one of these frontiers were to be developed.

Those impatient to dismiss and undermine the prospects of the "rival" frontier, only prejudice their own dreams. Meanwhile, it has been 40 years since Apollo 11 and will be 15 more until we are back on the Moon only to leave again. Let's do it right or not at all. **PK**

What is needed for a Mars to Stay Plan

- Arrive with shielding plan, water plan, energy plan, farm plan, machine/fabrication shop, ISRU facilities
- Total reusability and function reassignability for everything arriving on Mars except return vehicles NOTE: some return vehicles assigned to areosynch orbit to teleoperate probes in near real time. A fleet big enough to cover all of mars (120° apart and replacing one another for crew relief) = 6 minimum Other "return vehicles" used as Mars airplanes for manned scouting missions.
- Prior spin-up development of analog Mars building/ manufacturing materials
- Prior diversification of atmosphere mining products
- substantial, diverse, redundant yolk sac
- Solar sail pipeline already inaugurated
- Teleoperations forward base on Phobos, Deimos, or in Mars-synchronous orbit
- Site identification considerations
  - Thermal management (tropical site)
  - Water (e.g. *buried glaciers,* identified aquifer
  - All needed elements present *nearby*
  - High ground above possible flood line
  - Easy overland access to a wide area of Mars
  - Easy surveillance from PhD
  - *Proximity to tourist destinations*
  - *Proximity to Pavonis Mons* {premium site for west slope launchtrack, lavatube-ridden

Suggested Additional Reading

www.moonsociety.org/publications/mmm_classics/

"The Moon's Role in the Opening of Mars" - and - "Yolk Sac Logistics: a Strategy Tailored for Mars" - and "Pantry Stocking: the role of Creative Smuggling in the Building of Marsport"
MMM #113 March 1998 [MMM Classic 12]

"Tempering Enthusiasm for the Red Planet as 'The Next Human Frontier' with Personal Honesty" P. Kokh MMM #103 March, 1997 [MMM Classic #11]

"REDHOUSING: breeding 'Mars-hardy' plants in compressed Mars Air" - and-
"Mars will require a hardier breed of pioneer" P Kokh MMM #93, March 1996 :MMM Classic #10]

"Urbs Pavonis - the Peacock Metroplex: site for Mars Main Settlement" by Peter Kokh" - and -
The Mars Heritage Zoning Resolution" P. Kokh, MMM # 73 March 1994 [MMM Classic #8]

"Convincing 'Economic Case for Mars' Yet to be Made" P Kokh MMM - and -
"The Triangle of Earth-Moon-Mars Trade Routes" P Kokh MMM #62 Feb 93 [MMM Classic #7]

"Mars: plenty of time to wait, but none to waste" P. Kokh, MMM #54, April, 2003 [MMM Classic #6]

" Importance of Lunar 'M.U.S./c.l.e.' plan for opening Mars" P Kokh MMM #18 SEP 1988 [MMM Classic #2]

www.moonsociety.org/publications/mmm_classics/

Vision without action, is just a dream
Action without vision, is just activity
Vision and Action together,
Can open a new world.

MMM Platform for Mars, v. 2

MMM sees the following developments as part of "the critical path" to a successful opening of a human frontier beachhead on Mars.

- **Mars Permafrost Explorer** — The opportunity to pre-test such a probe in Earth orbit to improve knowledge of terrestrial tundra resources, makes this an easy sell.
- **Ground Truth Permafrost Tappers** — Orbital surveys will not be much good unless calibrated by scattered on site drill cores. Further, only by actual on site taps can we tell either the percentage of water content or its fresh-ness or salinity or how we can best tap the deposit.
- **Mars Lavatube Explorer Orbiter** - We can pre-test such a deep-penetrating radar probe in Earth orbit to improve our knowledge of lava flow terrain. The results could be far less important for geology than for future Mars settlement scenario options. Ancient near-surface Mars limestone caves might also be identified.
- **Mars Lavatube Entrance RobotIc Probes** - The recent development of the "Axel" "marsupial" rover that can winch itself down a crater rim, makes it possible to explore (7) recently discovered Mars lavatube entrances
- **Ground drilling probe to assay "buried glaciers"**
- **Mars topographic map** with accurate elevations: from which basin and watershed divides can be traced along with their overflow dam points. From this potential primitive and immature drainage patterns can be sketched, avoiding siting outposts in future flood plains.
- **Geochemical orbital mapper** — reflight of Moon Mineralogy Mapper (Chandrayaan-1) over Mars
- **Geochemical ground truth probes** — where needed to determine abundance, methods of production, etc.
- **Antarctic Mars Training Camp Base** in one of the cold "Dry Valleys" like **Wrigh**t or **Taylor.** A permanent faciity at which survival gear and methods developed for the Mars frontier can be tested, and expedition members trained.
- **Mars Analog Program II**
  - Modular Marsbase that can grow
  - Modular biosphere contributions in each module
  - Shielding: thermal management/radiation protection
  - Year-round real biowaste management, agriculture
  - Experiments: using Mars regolith simulants to pre-develop Mars-appropriate building and manufacturing materials
  - Compare productivity of teleoperation with Mars-Deimos equivalent time delay (0.2 seconds) vs. Earth-Mars equivalent time delay (6-40 minutes)
  - Experiment to find the smallest crew complement that embodies all needed frontier talents *with redundancy*
- **"Redhousing Experimentation"** Breeding "Mars Hardy" plants to survive in compressed (0.1 atm) Mars Air (CO_2).
- **Predevelop a Mars atmosphere organic chemical feedstocks industry**" with simple methods to mass-produce as many useful compounds as possible our of Mars' atmosphere (carbon, oxygen, hydrogen, nitrogen).

"The human race shouldn't have all its eggs in one basket, or on one planet. Let's hope we can avoid dropping the basket until we have spread the load." -------------- Stephen Hawking

Without Lunar Settlements we have No Real Economic Case for Mars

By Thomas Heidel

Introduction

At first look, Mars has enormous advantages over the Moon as a future human frontier. It has a thin but still considerable atmosphere rich in Carbon, Nitrogen, and Hydrogen, all elements present in barely minimal abundances on the Moon, and all necessary for life support. These elements can also be made into feedstocks for a an organic chemicals industry: fuels, plastics and other synthetics upon which modern lifestyles are based.

There are also significant reservoirs of water ice both at the poles and below the surface. Mars is a place that could be terraformed, or better, to use Kokh's word, "rejuvenated", restored to its warmer, wetter self, as an authentic compromise between Martian and Terrestrial conditions, with humans also adapting to meet Mars "half way" so to speak.

Psychologically, Mars' bright sky is much easier to live with than the Moon's "black sky blues." But both worlds "as is" provide monotonous color schemes and without redress, significant visual color deprivation. On both, however, redressing this condition is easy enough.

Mars looks like our "Four Corners" areas where Colorado, Utah, New Mexico, and Arizona come together. That is deceptive, because the temperature range is much closer to that in Antarctica, which only "looks colder." Unlike Mars, Antarctica offers sweet fresh air, and abundant off-shore food. Yet no one seems to want to settle there. That suggests that many would-be Mars settlers are in denial about living conditions on Mars.

Mars Economics 101

But this article is about building an economic case for Mars. The first, perhaps most salient fact is Mars much greater distance from the Earth-Moon system, and the infrequency of launch windows for Hohmann transfer trajectories between Earth and Mars: every 25.5 months.

That fact alone sets up a significant distinction between the Moon and Mars as potential human frontiers. A lunar frontier can grow at the end of an "**umbilical supply cord**." If need be, flights between Earth and Moon can be managed daily.

Mars, in contrast, has to develop as does the chick from the egg, feeding on a "**yolk sac**" that will provide everything needed until the next "shipment window" if not twice as long for insurance against shipment delay to the next window.

Quid pro quo

Regardless of how often shipments arrive to sustain growth, or at least to maintain the current state of development, benefactors on Earth, be they nation states, corporations, rich individuals, or more likely some ever changing mix of the above, without something coming back from these frontiers by way of at least partial payment, the outward flow of investment is likely to dry up, leaving the pioneers in a bad fix.

On the one hand, lunar pioneers are going to have the bigger challenge in becoming self-reliant. On the other hand lunar pioneers will have a significant advantage over their Martian counterparts in providing a mix of goods and services to the ever-expanding terrestrial econosphere with which to make significant payments for investments made.

The reasons are simple. The Moon is two orders of magnitude closer to Earth in both distance and in ease and frequency of travel. This makes it possible to lunar source building materials needed for the inevitable very significant buildout of facilities and installations in Earth orbit, both LEO, but more especially in GEO – Geo-synchronous Earth Orbit. Here will be built giant platforms at each location 2° apart (by international agreement) that will offer station-keeping, power, and communications, as well as robotic servicing to tele-communications satellites, GPS Systems, power beaming relays and solar power satellites. GEO will become an ever growing and significant part of the terrestrial "econosphere", and that will be in large part due to the availability of lunar building materials.

What can Mars sell to Earth?

We can think of nothing Mars can produce that can't be made on Earth. Let's not hold out hope for some unobtanium exotic element or ore. Let's not hold out hope for enormously useful and valuable pharmaceuticals or perfumes derived from Martian microbes. That would be a bonus, yes, but there are currently no grounds to hold any reasonable expectation of this type.

Tourism?

You can go from Earth to the Moon for a month, for a week, even for a weekend. Time is money! A round trip to Mars? Better set aside one to two years. Someday down the line, maybe we can get there in back in half a year with nuclear rockets? Yes, there will be tourists on Mars, but only a very tiny fraction of the volume of tourist business the Moon will enjoy.

However, the production of tourist travelogues and documentaries (3D, even holographics) for virtual tourism of Mars by Earthlubbers and Lunan pioneers alike should find a steadily growing market. The development of "Cycling Cruise Ships" may significantly increase the number of retired persons who will choose to make a once in a lifetime trip to Mars

Recorded telecasts of Martian exploratory expeditions, Martian sports events, performing arts, etc. will have a small dedicated market. But income from all tourist sources, actual or virtual stay-at-home, will be a very minor source of income for the pioneer economy.

Another difference from the Moon will result from the significantly longer time delay, a minimum of 6-40 minutes as opposed to a bit less than three seconds. This will make interplanetary interviews difficult and awkward to say the best, and most likely canned edits that flow unnaturally.

The Moon, not Earth, will be Mars principal market

1) volatiles – the Moon has barely enough hydrogen, carbon, and nitrogen (the latter in least abundance in proportion to need) to support tightly recycling mini-biospheres for its settlements. Mars atmosphere has plenty. But there may be another source in the Mars system: Phobos and Deimos were once commonly thought to be captured carbonaceous chondrite asteroids rich in these volatile elements. That expectation is no longer so confidently held. The Russian probe ***Phobos-Grunt*** [Russian word for "soil"] hopes to pick up where two previous Soviet Phobos missions failed: to reach Phobos, and do a chemical analysis of its composition. If it turns out that either or both Phobos and Deimos are volatile rich, that will become the initial cornerstone of the Mars trade economy. Volatiles can be shipped in the form of liquid methane (CH4) and liquid ammonia (NH3) to the Moon at much less expense than from Mars' surface.

2) alloys - The Moon is as blessed in iron, aluminum, magnesium, and titanium - the four "engineering metals" - as is Mars. But the usual alloy ingredients (e.g. carbon for steel, copper and zinc for aluminum, etc.) are scarce on the Moon. Lunar metallurgists will no doubt develop second best workable alloys using the ingredients common on the Moon. But for uses where only the best will do, alloys produced on Mars and items made from them can be shipped to the Moon at lower fuel cost from Mars than from Earth. Of course, when time is of the essence, and the next launch window is far off, Earth contractors are going to get the order.

3) settlers - Lots of people sincerely believe that they would like to pioneer Mars. In our opinion, there numbers are as large as they are only because they are in severe delusion about conditions on Mars. As we pointed out, Antarctica is a much friendlier and less challenging place and there is no line of applicants for Antarctic openings.

But for pioneers on the Moon, Mars might be a piece of cake, a walk in the park, a step up. Seasoned immigrants from the Moon will be already hardened to a life style that left behind on Earth many pleasures and opportunities and gratifications. A frontier is a place where you willingly give up an easy comfortable life for a chance to start over "at the bottom" where you can make a difference and have a better chance of living a truly rewarding life. Lunan pioneers will be tried and tested, and have a much easier time becoming adjusted.

It would seem then, that both for a seasoned core group of new immigrants and for opportunities to sell goods and services, that the Moon will be a much more promising economic partner for Mars than Earth. That does not necessarily mean that the Moon should be opened and developed first before we think of opening Mars. Mars could be opened at the same time or just slightly after the first outposts on the Moon, and both frontiers would grow apace, as trading partners with a much greater chance of both becoming economically viable than if either was to try it alone.

Why the hostility to the Moon by Mars advocates?

It is clear that most Mars-firsters have not looked at the economics. Those few who have have forecast that we will find some kind of mineral unobtanium on Mars or some priceless microbe-mush extract. That's pure "Sci-Fi" at this stage. It could happen, but counting on it is not a rational way to ground the opening of a Mars frontier.

But we do need to open Mars as a second basket for humankind and Gaia. But discounting the Moon's key role in an Economic Case for Mars just shows plain old immaturity and pettiness, a willingness to cut off one's nose to spite one's face. We, future Lunans and future Martians, are going to be in this together or we will both separately fail.

Building the Economic Case for Mars tidbit by tidbit

Mars seems to have a relatively abundant source of copper. Copper is useful for many things (other than being the metal I find most visually beautiful). Its conductivity makes it a superior medium for electrical current than second best aluminum, which will of economic necessity be the electrical mainstay on the Moon. Copper is also the key alloy in making aircraft quality aluminum alloy. So for wiring needs for which aluminum cannot be made to serve, and for high-performance aluminum products, Martian copper will underpin one significant trade line fro Lunar markets.

We are sure that we will find other similar cases, many of them metal alloy specialties, but also other products that can be made on Mars, but not on the Moon, for which there will be a strong lunar market. A corollary is that these same items may be cheaper to ship to LEO and GEO than terrestrial counterparts, at least when shipping time is not an issue.

But again, it is difficult to see what Mars could export to Earth directly other than intellectual property including process licenses, entertainment products, and uniquely Martian arts & crafts for the extremely wealthy.

End run around the Launch Window Infrequency

Solar sail cargoliners would take a long time to reach Mars. But that is irrelevant, as they can be launched at any time to arrive at any time. Sent out at regular intervals, monthly, weekly, even daily, in pipeline fashion, these craft would circumvent the Lunch Window barrier. The pipeline would always be full with something always coming out the tap. It is absolutely essential that this technology be fully developed. *Support the Planetary Society Cosmos-2 project!*

Concluding Advisory

Mars advocates would do their own cause better service to realize that the Lunar and Martian frontiers will both have a much greater chance "to survive and thrive" as trading partners than as bitter rivals seeking to kill each other. "Cooperate, or die trying to be stupid!"

The author invites reader suggestions for more specific suggestions towards building a strong economic case for Mars. We need to build the case, not tear it down, and we don't build the case of Mars by attacking the case for the Moon, or vice versa.

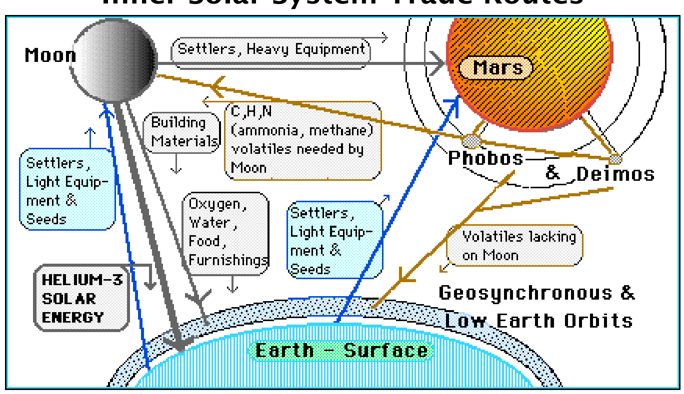
The author can be reached indirectly at
comfyrock@aol.com subject line "For Tom Heidel"

Appendix: Elements more common on Mars than Moon

Volatiles: Hydrogen, Carbon, Nitrogen; **Metals:** Copper, Zinc, Platinum, Silver, Gold, Lead, Mercury

Note: There has been greater tectonic and volcanic concentration of elements into "ores" on Mars than on the Moon, though not nearly as much as on Earth. That will make some elements, equally abundant on both worlds, easier to produce on Mars than on the Moon.

Inner Solar System Trade Routes



Editor: The above diagram is available as a slide transparency pdf file download at:
http://nsschapters.org/hub/pdf/SystemTradeRoutesTP.pdf

MMM #224 - APR 2009

IN FOCUS Space Debris and "The Tragedy of the Commons"

Not quite twenty years ago, in MMM #31, Dec. 1989, we ran an editorial, "**Space Debris: Cleanup and Prevention**." Yes, twenty years ago, the problem we face today, while now much more urgent, was clearly recognized. Then, as now, most talk is about finding ways to cleanup the mess, none at all about ceasing to contribute to it. Changing our dirty habits would be too .... *er, "inconvenient."* Why? That's easy. No space agency or contractor wants to stop doing what is easiest, continue to regard space as a bottomless sink for discarding the no longer useful - It is the "Tragedy of the Commons."

http://en.wikipedia.org/wiki/Tragedy_of_the_commons

If if (i.e. Earth orbital space) belongs to no one, no one will take responsibility for keeping it clean, and, in fact, no one has. "Would've, could've, should've." So we've messed up in a typically adolescent brat kind of way (if the shoe fits ....) There is no point in saying "I/we told you so." What do we do now? There have been put a number of schemes for cleaning up. All of these seem to suffer from significant ignorance of the size and scope of the problem. And most schemes totally ignore the most significant challenge, the velocity at which most pieces of debris are orbiting, not in some synchronized swimming type of way, but helter skelter from all possible vectors.

Cleanup is going to be difficult. No one scheme will tackle more than a portion of the mess. The most practical thing we can do now, while sadly we are still in the talking stage, throwing out wild ideas, is to rank the various schemes in terms of: A) to what percent of the debris is the scheme applicable? B) how much would the scheme cost? And C) How soon could it be implemented?

Meanwhile we could be more productively busy trying to figure out a set of internationally acceptable protocols to prevent adding even more to the current problem. What are we doing wrong? That's easy. We are acting like typical spoiled consumers, wrapping up our packages then ripping the packaging off without taking measures to do anything more than shove the wrapping and packaging detritus to the side.

Many rockets shed their farings at an altitude where atmospheric friction will soon remove them as a problem. But some make it to orbit and are just shoved to the side. We do not know what are the "most common" other sources of debris. But these need to be addressed. From the MMM #31 editorial:

"***We propose that the Moon Society and the National Space Society refine, and strongly advocate the following international conventions to govern future objects bound for low Earth orbits.***

1 Farings and payload shrouds must be so designed to remain attached to the host booster and must incorporate sail-like devices that will automatically deploy to accelerate atmospheric drag on such boosters so that their orbits decay in six months to a year.

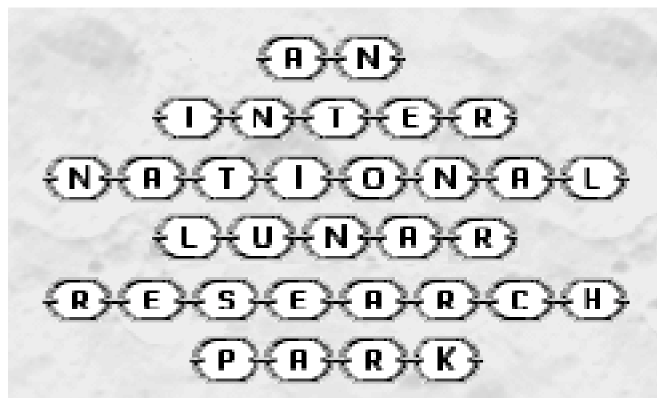
2 All payload satellites bound for drag-governed low Earth orbits (below 700 km) and not intended for intact recovery, must be equipped with a "dead-man's drag" folded sail device that will automatically deploy if power is lost, and which can be tele-deployed by ground controllers in other kinds of craft failure.

3 All orbit-bound payloads of a certain threshold size and weight must incorporate an internationally standardized grappling coupling.

4 Any orbiting payload or craft will be declared derelict by an International Board after failure by its launch agency to regain effective ground control within a two month period and if not retrieved or decay-accelerated by its owner or agent within a six month period, will be open to salvage of opportunity by any agent.

Space debris, already orders of magnitude more threatening than the natural micrometeorite, if shunted to the background of concern by apathy, has the potential to quarantine our species on our home planet. If we fail to rise to the challenge, we will deserve that fate.

Against any disease, and that's what space debris is, prevention is the first line of defense." **<PK>**



An Open-ended Lunar Initiative v. 2*

By Peter Kokh and David Dietzler

• V.1 published in MMM-India Quarterly (Feb. 2009)

Current Prospects

The United States, under former President George W. Bush, redirected its ISS and Planetary Exploration-focused Space Program to a "return to the Moon" and "beyond to Mars." This direction will probably continue under President Barack Obama. Meanwhile, China, India, and Japan have launched lunar probes and spoken of putting crews on the Moon. Whether these will be one time "science picnics" å la Apollo or real efforts to establish permanent facilities to support manned exploration sorties and other activities remain to be seen.

The Question

If each nation picks a different location on the Moon for its surface activities, areas of cooperation are limited to data sharing, tracking, and other support activities.

If, however, some or all national lunar outpost efforts are concentrated at one and the same location, be it at the north or south lunar poles or somewhere else, then the opportunities for shared facilities is enormously increased, and with it could come major savings by reducing unnecessary duplications.

Shared Facilities: Corporate Partners

Of course, then the question becomes "who will build and provide the facilities to be shared? And right here we have the opportunity to introduce new parties: contractor companies. Possible contractors could include Boeing, Lockheed-Martin, EADS, Antrim, and other names associated with the Aerospace industry, but also other major contractors. To pick a few: Bechtel, Halliburton, Mitsubishi, and on and on.

Added Players: Enterprise, University Consortia

If we collectively choose to establish not a collection of national outposts, collocated or not, but an "**International Lunar Research Park**" the possibilities for future expansion, elaboration, and outgrowth – *even into the 1st human lunar settlement* – will increase greatly.

Facility Lists

The lists below are meant to show how great are he possibilities for diversification and outgrowth. The items in **bold** will come first. Plain type next, *italics* last. Note, that this subclassification is just one person's first attempt, and corrective input is most welcome. No one expects to "get it right" the first time! What we want to do is to put out the general concept of how enormously the choice of an International Lunar Research Park could bust the future wide open. After the itemized lists (we surely have forgotten or not thought of many items!) we will give our thoughts on just what must come first.

National Outpost "Core" Elements

- **base habitat**
- **base laboratories**
- **basic life support**
- **command center**
- **airlock**

Contractor Corporation Services

- **Site preparation**
- **Spaceport services**
- **Construction equipment**
- **Shielding services**
- **Solar wind gas scavenging**
- **Fuel storage**
- **Fuel production**
- **Power generation**
- **Power storage**
- **Warehousing systems**
- **Thermal management**
- **Waste treatment**
- ISRU Research
- ISRU Manufacturing
- Habitat expansion modules
- Agricultural modules, basic agricultural services
- Biosphere maintenance
- Road construction
- Connector modules

Enterprise Opportunities

- **Commons with meeting space**
- **Restaurant**(s), **pub**(s)
- **Recreational facilities**: exercise, sports, dance, theater
- **TV/Radio Facilities, satellite communications telephone system, internet provider**
- Instruction, continuing education – keeping up to date with improved lunar systems
- **Financial services**
- **Hotel facilities** for visitors, tourists, overflow between crew changes
- **Cabbotage** (outfitting) services
- **Surface transportation (passenger, freight)**
- **Vehicle maintenance**
- **Space suit services**
- **Tools, equipment**
- Recycling services
- tour coaches & excursion services
- marketplace
- agricultural production, products
- green (horticultural) services
- reassignment services (new roles for scavenged parts of landers etc.)
- agricultural production
- customization services
- event management
- surface recreation vehicles
- archiving services

University Consortia

- **Medical Center**
- Continuing education
- Research facilities
- Astronomy installations

Joint Civic

- **Road planning local**
- **Road planning regional**
- **Environment protection**
- **Environment enhancement**
- **Inter-Sector coordination** (Contractors, Enterprise, National, University)
- Parks, parkways, gardens
- Outstation planning

Discussion – where you come in!

It would be miraculous if the list above did not have many holes, even if nothing was misclassified. Your input is most welcome!

The effort above is an attempt to start a discussion and to keep us, nationals of the various countries contemplating lunar surface activities, from being blindsighted to the enormous advantages to be gained not only by collaboration between the various national agencies, but *by restraining agency hubris and by taking the plunge to invite corporate, enterprise, and university consortia as equal partners in a joint "human" effort.*

The idea is for the national outpost agencies to buy or lease or tent equipment and services from the contractors and enterprises as their needs change and expand. This should provide not only substantial cost savings but a greater variety and supply of equipment and services.

Agencies need not provide quality and other specifications, because corpor-ate and enterprise personnel would be just as much as risk from improperly designed and manufactured equipment as would national agency crews. Toss out the mind-boggling bureaucratic paperwork, and down comes the costs.

Corporation employees would need housing, and all the other life support services as needed by the agency crews so it is natural, that as they begin to construct pressurized modules and other equipment from lunar building materials that they could provide for expansion of national outposts as well at considerable savings.

The national outposts would be "anchor tenants" so to speak, but as in shopping malls, in time their share of the economic value of total activities and facilities at the site might become, even though essential.

Some sort of Civic Council representing all of these Parties would be needed to make decisions that affect every-one, decisions about growth directions, environmental safe-guards, and so on. As this unfolds, the International Lunar Research Park will have become the first lunar settlement!

It is time for humanity to open the next continent, one across a different kind of sea. The "out of Africa" effort is ready for the next act. Only humans as a species, not horse-blindered agency managers, have the vision to grasp what is needed - and it is *not a collection of agency outposts!*

What Comes First?

Frankly, national agency planning puts the cart before the horse. Why? Two things come first, and no one is giving either of them more than trivial attention.

Part I: Developing *now* the Technologies needed for using lunar resources

We are not going to anything of lasting significance on the Moon unless we learn how to process useful building materials out of the elements in moondust. Known by the uppity Latin term *"In Situ"* Resource Utilization *("on location"* works just fine!) various processes have been proposed to isolate oxygen and other elements, but few have been tested either in laboratory scale or (more importantly) in mass production scale. How do we advance the "readiness" state" of these technologies? It is important to have them ready to go when we land on the Moon. Getting there, and then having to scratch our heads for additional time-wasting decades makes no sense. But that is the path we are on.

This topic is the subject of **"Improving the Moon Starts on Earth"** in MMM #s 132,133, Feb/Mar 2000.

Part 2 - Site Development

No site on the Moon, no matter what advantages are touted on its behalf, is anything but "unimproved" land, what in might be called "Florida swampland."

Before the first national agency manned lander sets down on a chosen site, it makes sense for a corporate contractor to have already "improved the site" - conferring on it various advantages that will make outpost deployment, construction, and operation so much easier. Indeed, Carnegie-Mellon University, a contestant for the Google Lunar X-Prize, has just proposed that establishment of the first spaceport be contracted to the university to be done by telerobotics.

www.post-gazette.com/pg/09063/952880-115.stm

This is the subject of the article, **"The Developer's Role"** from Moon Miners' Manifesto #131, December 1999.

Both articles are combined in one Online Paper:

"Improving the Moon & the Developers Role"

www.lunar-reclamation.org/papers/improving_moon_paper.htm

Also relevant, "The Outpost Trap" serialized in MMM #s, 198, 199, 200 September, October, November 2006

www.lunar-reclamation.org/papers/outpost_trap.html

<PK/DD>

Lunar Research & Development Priorities List: 1-5

By David Dietzler - pioneer137@yahoo.com

1a) Space Transportation: cheap access to space - CATS, from inexpensive expendable and/or reusable Earth to LEO launchers to ion drive or sail propelled craft for transport from LEO to LLO, L1, etc.

1b) Lunar derived fuels / propellants for lunar landers after some initial development on the Moon. Ion drives and sails are only good for cargos, not manned craft, given the great length of time they require for travel to LLO and therefore exposure to Van Allen Belt radiation, as well as life support. Thus we also need orbital fuel depot infrastructure. *The cost barrier must be broken.*

2A) Life Support Systems for prolonged (months, even years) human stays in space

2B) AI robotics for the majority of work done in space

3) Production of oxygen, other gases, metals and ceramics from lunar materials (some of this is included in category 1, for the production of rocket propellants on the Moon, given the assumption that lunar derived fuels will be cheaper than boosting them from Earth to LEO, although this assumption might be challenged depending on how much infrastructure on the Moon and in space would be needed, when it would be needed, how low the cost of launching to LEO goes, and how many manned flights would be called for given that robot power not manpower will do most of the work

Lots of research has been done on Oxygen production and most of it has been done with simulants only on laboratory bench top scales for short periods of time. Much more research must be done with real regolith using equipment that is built to work in vacuum, low G, hard radiation and temperature extremes for extended periods of time-years, not just weeks or months. Understanding the chemistry of regolith refining is just square one. A vast amount of R&D is required to build the equipment that does the work from shovel to final product and to determine which processes will scale up from the lab bench to the industrial level, work reliably for years in the lunar environment, demonstrate the greatest economy in terms of labor, time and energy required; require the least amount of input from Earth (some processes will require chemicals from Earth that must be carefully recycled) and the most amount of "Moon-makeablity." We will need to replicate this equipment on the Moon from lunar materials to expand production rather than constantly import devices from Earth hench the need for "Moon-makability" otherwise the cost of ISRU will be too high.

Prerequisite to production of lunar materials is energy production. It's going to take a lot of energy to smelt or refine regolith so we will have to land substantial payloads of reflectors, concentrating lenses or mirrors, solar panels, batteries and/or fuel cells and fuel cell reactant storage equipment, cables, switches, invertors and possibly small nuclear reactors. We will need to expand energy production as materials production grows and this takes us to the next category:

4) Lunar manufacturing: what to make and how to make it as well as what to make it from. Once we get past the hurdle of producing gases, metals and ceramics on the Moon we have to figure out how to make more devices for producing them from the gases, metals and ceramics available on the Moon. It won't be much use if the regolith refining devices require large amounts of gold, copper, zinc, flourine or other elements from Earth. We cannot upport huge masses of equipment, even with what passes for "cheap access to space" in the future, because even CATS will still be expensive compared to transportation on Earth. We must upport a seed of regolith refining and manufacturing devices that can replicate itself in order to refine more regolith and produce more materials as well as make things from those materials like solar panels, power storage systems, habitat, farm modules, robots, vehicles, machine tools and mass drivers for launching millions of tons of lunar materials into space for SPS construction.

To grow the mighty tree of space industry on the grand scale envisioned ever since O'Neill wrote "The High Frontier" from a tiny seed amassing perhaps just hundreds of tons will require a lot of brainpower, real world experience, and some sophisticated AI robot software as well as hardware. At this time even the experts can only take shots in the dark as to what that seed will consist of. It's fun to speculate about the payloads this seed might consist of, but only after some extensive R&D on the ground and on the Moon during NASA's RTM program and some high paid teams of mission planners have had years to work on this will we know exactly what the lunar industrial seed will consist of. Because of the high price of even CATS in the future it will be essential to minimize the mass of the lunar Industrial seed machines, maximize the use of local materials, and maximize the lifetime, durability and efficiency of the seed. Also, the seed must be reasonably priced. What good will it be to use a one-ton machine that costs a billion dollars if a ten ton machine can do that job and be transported to the Moon for much less than a billion dollars? In other words, when does miniturization start costing more than rocket transport?

As for nanomachines, I have no doubt that nanotechnology will be involved in lunar industrialization but I don't go as far as suggesting that a few kilograms of nanobots will replicate like a growing algae bloom and lunar colonies will emerge from that. I do not have anything against that scenario, I just don't buy it. I would love to be wrong but I suspect that lunar industrial seed will amass several hundred to several thousand tons and even that will be tiny compared to the millions of tons of lunar industry and SPSs that emerge from that over time.

5) Space construction. We have never built anything as large as a solar power satellite in outer space. What will it take to do this? We can presume that lunar aluminum, silicon and titanium, possibly some steel and glass, will be used but how will billets of metal from the Moon be turned into SPSs? What machines will be needed? How do we get those machines in space? Launch them from Earth or make them on the Moon and launch them from the Moon or will a combination of Earth launched and Moon made/Moon launched machines be used? Will we need a space colony and 10,000 space workers or will we just station a small human crew in space and use thousands of robots teleoperated by humans on Earth and on the Moon? **DD**

MAGNESIUM & IRON

Lunar Workhorse Metals

By Dave Dietzler pioneer137@yahoo.com

Outside of Convention

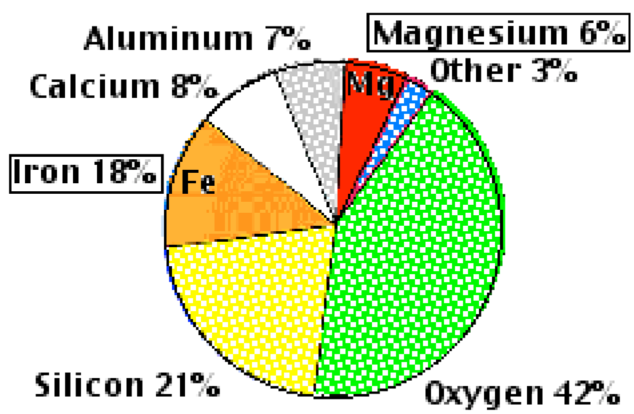
The literature contains many descriptions of processes for extracting aluminum and titanium from lunar regolith. Space colonies and solar power satellites have been designed that use these metals primarily. I will not elaborate on the processes for getting aluminum and titanium here. For the curious, see:

www.nss.org/settlement/ColoniesInSpace/colonies_chap07.html

and www.nss.org/settlement/nasa/spaceresvol3/plsoom1.htm

The difficulty with these processes is that they require substances not too common on the Moon like sulfur, hydrogen, sodium, carbon, chlorine, fluorine and/or lithium. There are lunar sources for some of these like troilite, FeS, of meteoric origin for sulfur that is sprinkled throughout the regolith. Hydrogen and carbon can be obtained by mining and roasting millions of tons of regolith. Sodium should be found as an impurity in oxygen from molten silicate electrolysis. Chlorine could be obtained by mining and roasting millions of tons of pyroclastic glass. Fluorine and lithium are especially rare on the Moon. Although aluminum and titanium production will not be impossible, this will be limited by the number of times upported reagents can be recycled and by leakage losses. It will also be limited by the quantity of reagents that can be produced by mining and roasting huge amounts of regolith and volcanic glass.

Magnesium and iron are two metals that can be obtained on the Moon *with processes that use only substances common and easy to get.*



Relative abundance of Iron & Magnesium in Lunar Crust

Magnesium

This metal might be overlooked because it is somewhat soft and burns; however, in a vacuum it will not burn and in air it is only likely to ignite if powdered or fine parts are being machined. Machining could be done in inert gas filled work chambers. As to its softness, it can be used for applications that don't demand a high degree of hardness and it has a very high strength to weight ratio that makes magnesium at times more desirable than aluminum or steel. Magnesium could be used for jobs that we might conventionally choose to use aluminum like railroad cars, rockets and spacecraft, ground vehicle frames and pressure cabins, and solar reflectors and supports. It is a slightly better reflector than aluminum.

On Earth magnesium is used for many products like auto body parts, wheels, engine parts, gear boxes, and sports equipment, for which light weight is an advantage. Baseball catchers' masks, skis, racecars, and horseshoes are made with magnesium alloys. Consumer goods such as ladders, portable tools, electronic equipment, binoculars, cameras, furniture, and luggage also benefit from magnesium's lightweight, and other applications make use of its ability to absorb vibration. It could be used on the Moon for these as well.

Magnesium can be welded with electric arcs and a helium shield gas. In the vacuum a shield gas won't be needed. Lasers are also good for welding magnesium due to their low heat input. It can also be cast in plaster molds, extruded and hot rolled. Magnesium alloys usually contain zinc, zirconium and aluminum. Zirconium might be hard to produce on the Moon, but some zinc can get obtained from pyroclastic glass and some aluminum should also be available. Rare earth elements from KREEP can also be used to alloy magnesium.

Mg could be extracted by removing magnesium olivine, forsterite (Mg_2SiO_4), from regolith with electrostatic separaters. Magnesium oxide could also be gotten by roasting regolith at 1500 C°+[1]. The olivine or MgO could be reduced with silicon in a flux of lime or calcium aluminate. Silicon or ferrosilicon can be obtained by serial molten silicate electrolysis. Calcium aluminate can be gotten by roasting anorthite or highland regolith at 1500 C.+. This silicothermic reduction process is most popular today and has replaced electrolysis of magnesium chloride for the most part. It is done at a temperature of about 1500 C. in a vacuum. The magnesium boils off and is condensed in the form of masses of metallic crystals. Solar or electric furnaces for this process could be made of cast basalt or glass bricks. Ceramic from magma electrolysis might also be used. The furnaces could be lined with titanium dioxide bricks because of their high melting point. The bricks could fit together like lego blocks and they would be welded tight with microwaves or electron beams.

Iron

Pure iron can be obtained on the Moon by magnetically harvesting meteoric fines that compose 0.15% to 0.5% of the regolith and are 5% nickel by mass [2]. Iron can also be gotten from serial magma electrolysis. Earthly cast iron is 3.5% carbon and is very brittle. Wrought iron is basically pure iron and these will have similar characteristics. Wrought iron has 40,000 psi tensile strength and 40,000 psi compressive strength. This may not be very high compared to steel and alloys of steel, but it is higher than that of unalloyed aluminum or magnesium. Before blast furnaces and Bessemer convertors wrought iron was the primary structual metal. So lunar pure iron should be respectable.

Rivets, nails, chains, railway couplings, water and steam pipes, nuts, bolts, handrails, roof trusses and ornamental ironwork were once all made of wrought iron. It was also used to make iron plates suitable for boilers. Blackplate consisted of sheets of iron thinner than plate iron [3]. To conserve carbon on the Moon, sheet iron instead of steel could be used to make studs for hanging cement board or drywall for walls inside lunar habitat.

Pure iron might be converted to limited amounts of steel on the Moon by using the old blister steel or cementation process, since blast furnaces and basic oxygen furnaces on the Moon are out of the question. Sheets of iron with carbon sandwiched in between or iron rods packed in carbon can be heated until they are cherry red in furnaces made of stone, cast basalt or ceramic. After several days the iron will absorb enough carbon to become steel. The steel is removed and melted down, perhaps with some calcium aluminate flux to absorb sulfur impurities, then cast and/or rolled. Carbon would come from scavenging of millions of tons of regolith. At the University of Wisconsin a Mark 3 mining robot has been designed. It could produce about 80 tons of carbon a year as well as substantial quantities of hydrogen, nitrogen and helium. Most lunar carbon will be used for biospheres, but if we devoted just 10 tons of carbon to steel production it would be possible to produce 1000 tons of 1% high carbon steel. This steel would be reserved for special applications like nuts and bolts, tools, cutting blades, drill bits, bearings and perhaps mining shovel buckets.

Works Cited

1) Rudolf Keller & David B. Stofesky of EMEC Consultants " Selective Evaporation of Lunar Oxide Components" reported in SPACE MANUFACTURING 10 PATHWAYS TO THE HIGH FRONTIER Proceedings of the Twelfth SSI-Princeton Conference May 4-7, 1995; pg. 130.
2) www.nss.org/settlement/nasa/spaceresvol3/lunarben1b.htm
3) http://en.wikipedia.org/wiki/Wrought_iron

[Editor: also see: MMM #118 SEP. '98 p 8. MAGNESIUM: Workhorse Metal for Europa, P. Kokh, republished in MMM Classic #12 p. 61 **D. Dietzler**

Commemorating the 40th Anniversary of the Apollo 11 Moon Landing

Apollo Moon Party Monolith design by Peter Kokh

A takeoff on the Science Fiction classic ***2001: Space Odyssey*** monolith, with the same power to bridge our proto-human past with our star-faring future. Lower half: etching of the recent photo of the earliest known human footprint, dated 1.5 mya; upper half: etching of the famed first human bootprint on the Moon from the Apollo 11 mission.

Buiilding Solar Power Satellites with "Lunar Materials"

SPS Material Alternatives

by Dave Dietzler pioneer137@yahoo.com

While Helium-3 fusion is but a theoretical energy option at this time, solar power technology is very mature. The only real barrier to space solar energy is the high cost of rocket transport, but this might come down in price in the future with standardization and mass production of private sector rockets for everything from communication satellite launching to orbital tourism.

Solar power satellites built from lunar materials could supply a large fraction of civilization's energy some day. They would probably be built in pieces or "modules" assembled at a space station at L5 mostly with robot labor and these modules would then be assembled into complete SPSs. The finer tasks of making the modules would be done on a large fixture that was part of the L5 space station that held the many pieces together as they were pieced and welded together and wired up by robots, some attached to the fixture and others moving around in space that use cold gas thrusters for maneuvering. Once completed, the module would be released and the coarser task of mating the modules together would be done by robots in free space.

Most of us have long presumed that SPSs would be made mostly of aluminum with silicon solar panels. SPS Illustration:
http://www.nss.org/settlement/ssp/SSP04-600.jpg

While **silicon** PVs will probably be used rather than solar thermal turbogenerators of much greater complexity that will also require more maintenance, is aluminum really the best choice of metals for the frame? Aluminum production on the Moon offers many challenges unlike iron and magnesium production, mostly because of the upported* chemicals and complex recycling equipment needed. Titanium production on the Moon is also less reliant on upported chemicals and recycling than is aluminum, barring the success of a device like Dr. Peter Schubert's all-isotope separator.

[*"upported" - this is a term coined by the MMM Editor many years ago Some have objected that there is no "up and down" in space. That is not quite so when you are dealing with steep gravity wells, such as Earth's. It is definitely "uphill" to the Moon.]

Titanium has the highest strength to weight ratio of any metal. In its unalloyed state it is as strong as some steels but 45% lighter and it is twice as strong as aluminum but only 60% heavier. *The mass of titanium required to build an SPS frame of equal strength, given Ti's superior strength to weight ratio, would actually be less than that for an Aluminum frame.*

So why don't we build SPS frames with titanium? Given the simplicity of Ti production compared to Al production on the Moon, barring an all isotope separator, Ti should be cheaper to produce on the Moon. Unalloyed titanium has a tensile strength of 63,000 psi. Plain 1000 series aluminum has a tensile strength in the range of 13,000 to 27,000 psi. The only element available on the Moon with which to alloy Al is magnesium. Titanium can be alloyed with aluminum. Although titanium is superior to aluminum in many ways, its cost is higher on Earth at least. The FFC process should reduce the price of Ti that has been produced by the Kroll process since 1935. Refining, working and welding titanium is difficult on Earth because of problems with contamination by atmospheric oxygen and nitrogen and this increases its price, but in the free vacuum of the Moon and outer space, this will not be a problem at all.

Numerous processes have been put forth for extracting aluminum on the Moon. They all rely on reagents like sulfuric acid, chlorine, carbon, sodium hydroxide, sodium carbonate, manganese and/or lithium fluoride. These processes involve numerous steps and elaborate equipment for the extraction of aluminum and the recycling of all the reagents. See:
http://www.nas.nasa.gov/About/Education/SpaceSettlement/spaceres/V-5.html *and*
www.nss.org/settlement/nasa/spaceresvol3/plsoom1.htm

Titanium production, by comparison, is much simpler. Ilmenite could be separated from mare regolith with electrostatic separators and treated with hydrogen obtained by solar wind implanted volatiles harvestors at about 1000 C. to obtain water that is electrolyzed to recover hydrogen and gain oxygen, and titanium dioxide mixed with iron. The particles of TiO_2 and iron could be heated in solar furnaces in the vacuum to boil off the iron and the TiO_2 could be deoxidized to get sponge or powder titanium in FFC cells. The FFC cells with their carbon electrodes and calcium chloride electrolyte would be upported. Unlike the electrolysis of aluminum chloride, chlorine gas that would have to be recycled does not evolve at the electrodes of FFC cells. Oxygen is released at the anodes of FFC cells and I have read nothing indicating that the carbon anodes burn up to produce CO or CO_2.

We must also think about reflectors to increase silicon solar panel output. These might be made of **magnesium** - a metal that can be obtained on the Moon without any upported chemicals by the process of silicothermic reduction aided by the free vacuum of the Moon. Reflectors will not bear any extreme loads and magnesium is only two thirds as dense as aluminum.

Aluminum will not be driven completely "out of the picture." We need it for wiring and cabling, although calcium might often substitute for it, and it is a titanium alloying ingredient. The most common titanium alloy contains aluminum and vanadium, but vanadium is present at only about 100 ppm in the regolith. We must look at other alloys of titanium made with aluminum, iron, manganese and/or chromium. We might obtain vanadium via bioleaching. Thin aluminum films deposited on thin magnesium sheets might increase reflectivity.

While aluminum is much cheaper than titanium on Earth, this might not be true on the Moon. Until we know what the economics of materials production are like with real world experience on the Moon, or some very clever foresight on Earth, decisions regarding material choices cannot be finalized. It would be very surprising if steel, given the rarity of carbon on the Moon, turned out to be the cheapest metal available on the Moon! <**DD**>

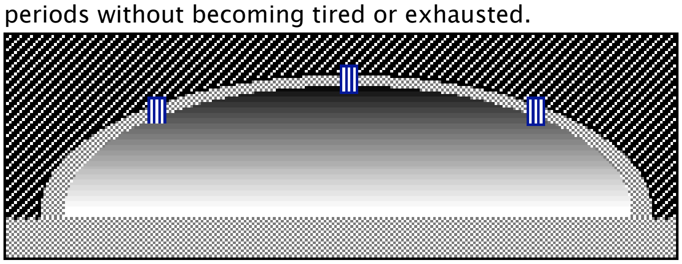
[Dave appends these helpful links and illustrations:
http://www.moonminer.com/Powersat-Fixture.html
Powersat Construction Fixture
http://www.moonminer.com/Lunar-Titanium.html
Benefitiation, Extraction, and Challenges of Titanium
http://www.moonminer.com/Regolith_refining.html
Refining Moondust

***Check out* www.moonminers.com** Dave's great site!

By Peter Kokh kokhmmm@aol.com

In his latest book, “**How to Live on Mars**” Robert Zubrin comes to the topic of skinsuits, that hug the body, allowing much greater freedom of movement, and with much less fatigue. That’s the good part!

While skinsuits will most likely be inferior when it comes to handling radiation and thermal extremes, these dangers are excluded in sheltered or shielded “lee” vacuum situations within lava tubes and in unpressurized warehouses and sports arenas (*illustration below*) that are sheltered from the cosmic weather. It is in these environments that we are to see widespread skinsuit use. Such suits are lightweight in comparison and allow much greater freedom of movement. More comfortable to wear, they will allow people to work and recreate for longer periods without becoming tired or exhausted.



See www.moonsociety.org/images/changing/lee-vac_arena.gif

Skinsuits are revealing

But we gain this comfort and ease at the price of embarrassment. Because a skinsuit is form-fitting, it will showcase all the varied imperfections of one’s own body shape. Potbellies, wide hips, flat breasts would all be revealed. Some of us will take that in stride. Others would predictably not be caught dead wearing such a suit.

Or so Bob Zubrin predicts! But there is an answer: lightweight *outerwear* that can partially moderate body shapes, and distract with color and pattern as well.

Skinsuit “Outerwear”

There could be hats, capes, robes, overalls; you name it. Meant for wear in vacuum over a skinsuit, these apparel items could be made of most anything cheap and easy to work with: woven metal fibers, even wires, yes even medieval style chain mail; scrap cardboard, fiber glass fabrics, metal plates strung together – the adventures of “trashure” (transforming trash into treasure.) Any material or style that will distract attention from bodily imperfections, yet not make movement cumbersome or awkward, will become something with which to experiment. And for inspiration; anything from historical periods, from science-fiction/fanstasy, from imagination is fair inspiration for creative designers.

One can imagine periodic fashion shows in Luna City, perhaps in a lee-vac arena, where models with very imperfect physiques, both male and female, would strut down a runway before onlookers behind glass observation areas, with a variety of materials, colors and designs.

Over a skinsuit, of course! Whether stylish, fanciful, sheer fun, what does it matter? Skinsuit outerwear fashions will say “we belong here, out on the moonscapes!”

This may become an anticipated periodic event even for those not anticipating lee-vac or out-vac excursions. With successive shows, and over the years, skinsuit “outerwear” items available in Luna City retail shops will grow in number, design variety, and sophistication.

Start of a Cottage Industry

Periodic fashion shows should be popular, and drive a startup cottage outerwear fashions industry. Over time, more and more pioneers, whatever their physique, will feel encouraged to explore what the out-vac and lee-vac environments have to offer. And for those venturing out, the great variety of outerwear fashions would make emergency identification easier, and people watching that much more fun.

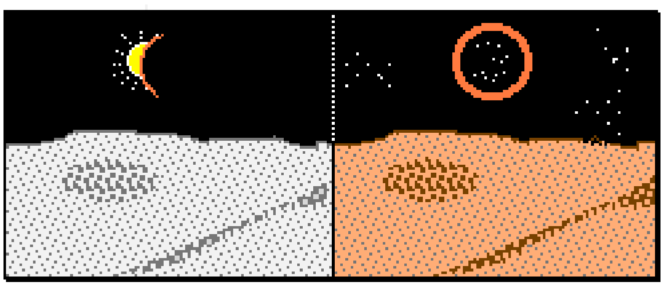
Skinsuit outerwear and new performing arts

Lee-vac activities would become more varied as well. Can you imagine ballet not only in one-sixth G, but in vacuum as well? Lee-vac arena sports team uniforms would be more interesting and fanciful as well - all part of team sports enjoyment.

Beyond the protection of "lee" space

But these "fashion" developments might also encourage more and more lunar residents to wear skin-suits with outerwear even in full out-vac, the unprotected "vac"uum "out" on the lunar surface. Such sorties would be less risky during the "moderate risk" conditions of "early morning" days and "late evening" long shadow days. Remember it is not quite 15 days from lunar sunrise to sunset! Temperatures will be lower, but not the radiation level.

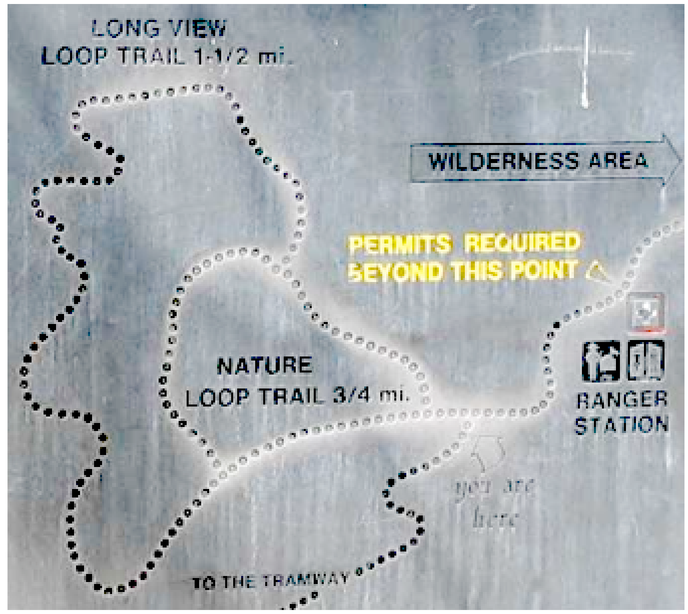
Another "low risk" opportunity lies during the1-3 hour long solar eclipses when the surface of the Moon is lit with the ruddy light of the ring of sunrises and sunsets that circle Earth when Earth itself is blocked out as the sun slips behind it. (An event paired with total lunar eclipses seen on Earth.) During such periods, the out-vac will take on the appearance of marsscapes in twilight!



Every now and then, Earth-facing moonscapes take on the hues of a dimly lit Mars. But there will be no mistaking where you are. In the sky in place of Earth will be a black hole outlined with a ring of orange tones with only one ten thousandth the brilliance of sunlight. And in that black hole, clusters of lights, Earth's cities and fires, dotting otherwise dark continents. It is Umbra. * See MMM #164 p. # - APR 2003.

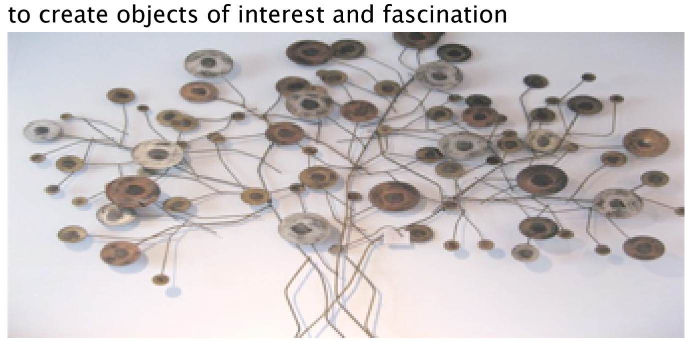
Surface paths and trails for strolling

But before such surface recreational strolls can become popular there needs to be some encouragement in the form of "excuses to venture out:" something worth going out on the surface to see and experience. Most people will not just wander out on trackless wastes just for the sake of doing so, at least not often! But Luna City Fathers can encourage people to get out from the confines of the settlement encouraging the creation of "nature" paths that showcase local geological features of interest. Compacted and sintered, these paths will be relatively dust free yet allow enjoyment of the "natural" moonscapes to either side. Such a path could encircle the settlement, with bridges and underpasses where the path intersects roads into and out of the settlement. After sundown, rocks and cut breccias selected for phosphorescence could trace the way.



Art and Sculpture along the way

Sculptures of an ever more varied variety and originality along such paths could also attract exo-pedestrians. In turn, the opportunity to have their works seen and admired by many will encourage artists and sculptors to create objects of interest and fascination



Fanciful metal sculpture "moon shrub?"

Free scrap metal is manna from heaven for sculptors

. There could also be benches, each of a unique design (how about a pioneer design competition to stir extra interest?) and an objet d'art in itself would encourage walkers to take a rest, the better to appreciate the art and views along the way.

Animated Sculpture

On Earth, mobile sculptures are powered by the wind or sun. On the Moon, the solar wind blows at hundreds of miles per second, but is too thin and lacks the oomph to power anything. What about solar power? Solar panels could easily drive small motors and actuators to create mobile sculptures on moonscape paths and trails frequented by walkers after sunrise and before sundown. They'd work during high noon, of course, but few people would venture out on the trails at those times.

Let's use our imagination! Solar powered animatronic guides to explain landscape, rock, and geological features? Even programmed to answer routine questions? {"Where is the nearest restroom?" "Are there any vending machines nearby?"). Why not fanciful alien creatures that would leap out from behind a boulder to scare and delight children? Holloween when it occurs near local sunset could become a trail-event must!

The oldest, easiest hobby?

But perhaps the most interesting things to observe and study will be provided by the walkers themselves. They will no doubt appreciate this special opportunity to partake in the perhaps humanity's oldest hobby: going somewhere *just to see and be seen - people watching!* "Oh look at what she's wearing!" "If he thinks we can't see that he has a potbelly, he's fooling himself."

Bringing the Lunar Frontier to life
while preventing neurosis and psychosis

Is all this idle diversion? What has all this got to do with anything? Getting pioneers to venture outside the pressure hulls of their settlement is absolutely vital to the long term mental health not just of individuals, but of future lunar frontier society in general. We on Earth see the lunar surface as hostile, barren, life squelching, and some thing to be avoided at all costs. To tell the truth, those of us who see it that way are poor settler material.

It is imperative that the pioneers learn to make themselves feel "at home" on the Moon *not just within their comfortable settlement homes and commonspaces, but out on the surface as well.*

The penalty of not doing so will be neurosis and psychosis not just of individuals, but very likely of lunar frontier society in general. If we are going to make ourselves at home, we need to do it in a "no holds barred" fashion.

Life-squelching cosmic rays and solar flares?
Tissue-burning ultra-violet?
The incessant micrometeorite rain?
The insidious, potentially poisonous moondust?

A lesson I learned from my mother is that *"every apparent disadvantage remains so as long as we are looking at it wrong."* "Change your attitude and try to see how that feature can be turned into an opportunity!" Then you will see it in its true light for the first time!

` Not a common attitude to be sure, but try it! It works. Now that's the stuff of which those pioneers who will survive and strive will be made of. Attitude is everything, and the naysayer, the timid, the "Oh, we can't ..." crowd just doesn't get it, doesn't understand, and we have to ignore them and move on. The Lunar Frontier is our dream not theirs, and it is ours to pursue. The above attitude works on everything: from apparent life setbacks to obstacles on the road to the Moon and beyond.

Beyond the visions of "fellow travelers"

Some "pro-space" writers want to see robots do everything. "There is no need to put humans in such alien and hostile and god-forsaken places," they advise.

But they have it all wrong. Venturing into new turf, into spaces that at fist seem hostile to human life, is something we have been doing *even before leaving our homeworld in Africa* to settle the rain forest jungles and the parched deserts of the first human continent, in a journey that would someday see us settle the north arctic which would have seemed as life-squelching to an early African in what is now Kenya, as life on the Moon must now seems to many of us incapable of getting past intimidating first impressions.

We have got to where we now find ourselves, a truly global species, by venturing into one new land after the other, where the wildlife, the vegetation, the climate, and the available resources were different from where we came from, from what we were used to and had taken for granted. And guess what? Each time we learned to make ourselves at home. Each time we learned to live with the "dangers" and "challenges" posed by the new territory.

From a more meta-historical vantage point, each time we developed ever more of our amazingly adaptive unsuspected human potential. Each time we realized more *hidden human talents.* Each time we brought out more of the potential that gives glory to the creative agency or agencies that have driven us and drawn us forward and upward. Why would some put a cap on what we humans can do? A cap based on past accomplishments in Africa 200,000 years ago would have been quite immature. A cap based on our accomplishments to date in the early 21st Century would be just as premature. Our fellow travelers, those who would see robots explore space and access its resources but leave humans at home, are just that. Fellow travelers. We can use their limited support, *but we must never accept the limits of their vision.*

So you thought that this would be just a "far out" article on whimsical spacesuit outerwear fashion! *Everything bears on everything else.* Where we are and where we will be in the future is a web of endlessly varied possibilities. *Let the adventure never end!*

The Moon, its capacity to support a full flowering of human life quite unsuspected, will be the first of many new worlds. Why should this surprise anyone. Every element in our bodies, and in everything we see around us, other than hydrogen which is primordial, originated in the furnaces of star core explosions.

"Of stardust thou art
And to the Stars thou shalt return"

Now that is a "pilgrimage", a "directive", that will take us centuries, millennia, maybe eons to pursue. We are at the "baby's first steps" stage, the most critical of all. We have yet to truly integrate Antarctica into our human metaworld, and timidity, self-doubt, and endless diversions threaten to stifle our next frontier-exploring efforts. Are humans up to the challenge? Despite every thing that should give us pause, a look at our past should encourage us. *We have always taken that next step* and we have *always succeeded*. Now is certainly not the time to doubt either our own capacities our our destiny.

But each time, only a few pioneer the new "world" and they do so despite the discouragement and disinterest of the many who remain behind. **<MMM**

Call for a Global Space Revolution

by Shaun Moss 2009-03-21 shaun@starmultimedia.biz

The world stands on the brink of imminent global change. The challenges currently being presented to human society by instabilities in the global climate and economy are significant; finding solutions will assuredly occupy much of our attention over the coming decades.

However, in perfect balance, we also find ourselves at the doorstep of the greatest evolutionary leap that Earthian life has encountered since it crawled out of the oceans. We are poised to enter space - not simply as a handful of select persons or machines, but as a species.

The development and implementation of new systems for global environmental and economic management is widely understood to be of the utmost urgency, and, fortunately, steps are already being taken in this direction by great leaders and thinkers around the globe. However, what seems less apparent are the astronomical rewards for humanity that will result from our expansion into the Solar System.

The potential benefits of space exploration and colonization include:

The Overview Effect

By all reports from astronauts, nothing compares with viewing the entire Earth from space. From this perspective the planet appears as a single, whole entity: a shining jewel, a living, breathing organism with no borders or other visible signs of separation between its inhabitants. It becomes more difficult to imagine that one is from any specific city or nation; rather, one sees the entire planet as "home". From space, all people and nations are equal, bound together by the one thing we all have in common - the planet that we are all part of.

This perspective of Earth will lead to a greater unity among its peoples, an effect that will only increase as we colonize other worlds such as Luna and Mars. From space, any place on the surface of Earth is equally accessible; the differences between so-called "developed" and "developing" nations are not apparent, and indeed, from this perspective it becomes difficult to understand why such extreme variations in economic standards exist on the surface.

This profound shift in human consciousness from viewing Earth as a collection of distinct tribes to a single living world, experienced by increasing numbers of people, will automatically lead to the formation of new strategies for global environmental and economic management.

Access to Abundant Resources

Space is infinite, and contains infinite energy and material resources. By developing the necessary technologies and systems, humans can access these resources.

Once you see beyond religious, ideological or other purported reasons, conflict on Earth is almost always about natural resources such as energy, metals or land. Although limited on Earth, all of these are available in extreme abundance in space:

- Solar power, collected in an environment where the sun never stops shining and is never occluded by clouds or dust, can be efficiently and safely beamed to Earth (or anywhere else in the Solar System) to provide continual, limitless and reliable energy.
- Over 400,000 asteroids have been identified in our Solar System, with more being discovered all the time; the estimated total is over 1 million. Many of these orbit near Earth, and many are composed of almost pure metal, while others are plentiful sources of carbon or water. Access to these resources will mean an improved Earthian economy, reduced need to damage Earth's environment through mining, reduced international conflict, and an abundance of the necessary materials for constructing space cities and vehicles in Earth orbit and other locations throughout the Solar System.
- Mars has a surface area approximately equal to the land area of Earth. The colonization and subsequent terraforming of Mars will therefore provide the human race with almost double the territory in which to live. This will only be the beginning; the experience of inhabiting and developing just one such planet will teach us how to colonize many thousands.

Survival

While infrequent, it is known that mass global extinctions caused by asteroid impacts have occured several times in Earth's history, and will almost certainly occur again. Hence, in order to ensure the long-term survival of humans as well as many other Earthian species, there are only two reasonable options:

1. Establish human colonies at other locations in space, so that in the event of a major impact the human species will survive and may potentially re-inhabit Earth afterwards.
2. Learn how to modify the orbits of asteroids, or how to break them into smaller pieces, so that a potential extinction-causing impact can be prevented.

Both of these solutions require increase technical capability in space.

If an impactor is above a certain size or velocity, it will impossible to divert or destroy it; furthermore, extraterrestrial colonies will probably be dependent on resources from Earth for centuries. Hence, the optimal strategy for the long-range survival of humanity requires both of these solutions.

Increased Global Collaboration

At our current level of technology, exploration and development of space is still fairly expensive and complicated. Furthermore, considering that the effects of space research are often global in application rather than restricted to specific nations, there is overwhelming incentive for international collaboration in space activities. This has been one of the primary benefits of the International Space Station, which has brought together some of the greatest countries of Earth into a noble and productive exercise.

During the past century several arenas of activity have replaced military conflict, including sport, tourism, international trade, political union, and collaboration on technological development. The nations of Earth have started to realize that co-operation, instead of competition, leads to an improved outcome for everyone. By building on the success of the ISS and continuing with international collaboration on space development, the nations of Earth will be drawn into an even closer partner-ship. This can only lead to peace and an improved quality of life for everyone on Earth.

Technological Innovation

Countless examples already exist of technologies that were developed for space and have since been applied on Earth (computer technology, structural analysis, the hand-held video camera, communications, IT, sports training, energy storage, robotics, materials, etc., etc.). The question is, would these technologies have still been developed if people were not striving to solve difficult problems in space?

When given an inspiring and challenging problem, the human mind begins experimenting with solutions and gathering information, both consciously and subconsciously, with the result being eventual inspiration and breakthroughs. The challenging environment of space presents unusually hard problems, which thus tends to attract the most brilliant minds, resulting in especially innovative solutions that can have enormous application and value on Earth.

For example:

- Technologies developed for space settlements, such as atmosphere processing, in-situ resource utilization, recycling, etc., can similarly be applied to open up huge uninhabited regions of Earth, while also improving the efficiency and function of existing cities.
- Advanced robotics technology developed for exploration, mining and construction in space can be applied on Earth to an extremely wide variety of tasks, decreasing the cost of materials, products and services, and improving health and safety.
- Energy production methods developed for space applications, such as space solar power or nuclear fusion, can be applied on Earth to provide abundant electricity and thus improved quality of life to all people.
- Biotechnology developed for space agriculture or terraforming can be applied on Earth to drastically improve global food production and health.
- Carbon nanotube technology developed for space elevator applications can be applied to create all manner of ambitious structures and equipment on Earth, as well as space structures and vehicles.
- Planetary engineering strategies developed for terraforming Mars can be applied to Earth in order to improve the global environment, including cleaning the atmosphere and oceans, bringing life to the deserts, and stabilizing global climate.
- Vehicle technology, developed for space applications, will increase the speed and lower the cost of travel on Earth, vastly improving the efficiency of human transport, resource distribution, package delivery and emergency response.

The colonization of space offers hope for humanity. It is simply the only path to an abundant and peaceful future for an expanding human civilization. It will bring us everything we need to develop and grow; without it, our future will be one of increasing restriction, compromise, difficulty and conflict. If the number of people continues to increase while the amount of available resources remains the same, then, logically, this means a reduced share for all. The only other option is population control, which is not freedom; in fact, it would require increasing control by global authorities, and we would ultimately lose many of our technological capabilities along with our peace and freedom.

As an analogy, consider a tribe living on a small island. Their population steadily increases, but the amount of land they have available to grow food remains the same. They know that across the sea is a large, uninhabited continent with abundant resources, but they decide not to risk investing in trying to reach this place, and to focus all their energy on the immediate problems of survival. Eventually they begin to fight over the dwindling resources and further damage is inflicted on the island, and the tribe, until only a few remain to pick up the pieces.

Compare this with another tribe in a similar situation. They, too, are growing in number and approaching the population limit that the island can sustainably support; they also know about the abundant resources across the sea. Even though they are experiencing challenges, they realize that these problems will only get worse unless they find a way across the sea, so they begin researching boat technology while also tending to their immediate problems. This tribe is more optimistic – they know that their problems are temporary, and that soon a new era in their civilization will begin: one of peace, expansion and security.

At this juncture in human history, with the challenges that now lie before us, opening up space should be made an absolute global priority. It should not be something of marginal interest, or a heavy load to be pulled along by a dedicated few, or something we will do "when we get around to it" or "when things are better". The sooner we become a space-based civilization, the sooner tensions on Earth will be relieved and we can enter an golden era of peace, harmony, expansion, abundance, adventure, freedom, health and happiness. It should be commenced immediately, and should be undertaken with wholehearted passion and commitment by the entire global community.

The following strategy is suggested:

1. The establishment of an Earth Space Consortium (ESC) comprised of governments and government agencies, private corporations, academic institutions, space advocacy groups and philanthropists. This organization would be funded by both public and private money, with each member contributing an appropriate percentage of GDP or profits. The function of the ESC will be to organize a substantial fraction of Earth's resources (in particular, at least 10-30% of Earth's finest minds) into a unified and cohesive strategy for providing the people of Earth with access to the abundant resources and limitless expanse of space.
2. Government-sponsored financial benefits, including tax exemption or discounts, and/or investment, should be available for all companies involved in space exploration and development, environmental engineering, and the development of critical enabling technologies such as aerospace vehicles, solar power and robotics. This will hasten the development of solutions to immediate global problems, and more quickly secure a better future for all people.
3. A dedicated, coordinated and well-funded global program for reducing the cost of access to space. Everything depends on it; at this point, the primary obstacle preventing humanity from becoming a space-faring civilization with the resources of the Solar System at its fingertips is the exorbitant cost of reaching free space from Earth. The initial phase of a unified Earth space program should be primarily

focused (90%+ of expenditure) on advancement of space transport technology.

4. A global program to develop space solar power as a method of providing continuous, reliable and abundant clean energy to Earth, while simultaneously increasing our capabilities in space and developing technologies for on-orbit construction.
5. A global program to develop space tourism as a viable economic motivator for the private space sector, a source of inspiration and adventure to the people of Earth, and an essential precursor to space property development and colonization.
6. Development of a robust and profitable space mining industry. This will simultaneously provide three enormous benefits: an economic incentive for space development; a great abundance of metals, carbon, water and other materials necessary for construction of a space civilization; and the development of technologies and methods for defending Earth from asteroid impacts.
7. An international collaborative effort to establish permanent human settlements in Earth orbit and on Luna and Mars. These seeds will become new branches of human civilization, thus ensuring the long-term survival of humans and many other Earthian species. The exercise will also teach us about advanced recycling, nanotechnology, robotics, resource management, advanced biology and chemical engineering, planetary engineering, the successful formation of harmonious, close-knit communities, and many other things that can be applied with tremendous benefit on Earth.

The time is now. It will only become more difficult over the coming years. The past doesn't matter, and neither do our petty conflicts over resources; all that matters now is creating a positive future for ourselves and for our descendants. The sooner we make space development our utmost priority and open up space for the people of Earth, the sooner we will enter an amazing new chapter of human civilization. We need to pull together as a team, get organized and focused, and create an exciting new future of peace and freedom - in space. **<SM>**

Shaun Moss was born in Melbourne, Victoria, Australia, but has lived most of his life in Brisbane, Queensland, Australia. Shaun has been a Moon Society member since shortly after the Society was formed. Earlier this year he joined the Moon Society Leadership Council and in August will become a member of the Board of Directors.

Shaun has been quite active in our new Town Meetings, and took the lead in formulating the Society's first "Town Meeting Project," the Apollo Moon Party, to commemorate and celebrate the 40th anniversary of the first manned Moon landing and Moonwalk. Widely traveled, Moss brings an international perspective to his work and to the organizations to which he belongs.

Shaun, like the editor, has also long been a avid member of the Mars Society, and tends to see things in perspective of how both frontiers can open together and to each other's benefit. See his editorial in MMM #223.

He hopes to unveil his new project shortly, the new interactive www.moon-mars.com website, which will serve enthusiasts of both frontiers. **<MMM>**

Things May be Simpler for Lunar Engineers

By Dave Dietzler pioneer137@yahoo.com

The lunar manufacturing engineer wonn't need to worry about jet engines, diesels, gasoline engines, steam turbines, petroleum refining, hydraulics, pneumatics or a whole host of other Earthly technologies. Tasks will be:

- Welding w/o the hassles of oxygen
- Rolling flat plates of metal; welding up "boxy" things
- Assembling parts made by 3D sintering
- Conventional casting and machining operations
- Making solar panels
- Batteries and/or fuel cell systems
- Electric motors of various sizes for everything from ventilation fans, O^2 compressors, water/sewage pumps. vehicle propulsion, heavy equipment power
- Mechanical arrangements using pulleys, augers, etc., to replace hydraulic and pneumatic devices
- Automating all the above with robotics

We can now see how to make all sorts of things on the Moon. The 2nd toughest challenge is making all the electric motors we will need. We need some sort of X-prize for anyone who can devise an electric motor manufacturing facility design for the Moon. The toughest challenge will be automating all this with robotics.

1. Artist renditions of stuff on the Moon are deceptions. Their stuff is all tubular, curved, domed and stream-lined. That's too complicated to make. From mining shovel buckets to vehicle cabins to RR cars and habitat modules all we need are rolled and cut flat plates welded up into all sorts of "boxy" shapes.
2. NASA stuff is all very complex, microminiaturized, lightened, exotic and expensive so they can rocket it up there. Stuff we will make on the Moon could be much simpler, thus cheaper.
3. The lunar mining engineer's job is simplified because 99% of the mining will be strip mining. We might blast and tunnel a little bit into central crater peaks if there's anything of value from upthrust deep strata inside. Drilling for volcanic gas? Maybe. And there's no ground water to deal with. Less gravity = less cave-in danger.
4. The lunar architect and civil engineer's jobs are simplified because there is no wind and no ground water to contend with and less gravity. These are the guys who will use cast basalt (bricks, pipes, tiles), glass, glax, concrete, cement board, drywall and loose regolith for much of their work, as well as iron plates.
5. Lunar electrical engineer must learn to do everything with aluminum and calcium wire; and upported super-conducting wire. Solar panels produce DC so we will use a lot of DC electrical stuff. As superconductors can transmit DC as easily as AC, we won't need trans-formers and substations. We will transmit 110V current for thousands of miles over the Moon with SC wires.
6. Furniture, housewares; all stone, metal and glass. No wood means no carpenters, but we might saw and nail together aerated autoclaved concrete stuff.
7. Chemical engineers won't do much organic chemistry outside of small laboratory workshops for small batches of plastic and silicones. The metallurgy guys will have to figure out how to make smelting furnaces and other stuff out of local materials for producing materials from Moon dust.

So can we industrialize the Moon? I think we can. Many things will be simpler. **<DD>**

MAGNESIUM

Workhorse Metal on the Moon?

By Dave Dietzler pioneer137@yahoo.com

Recently, i experienced a paradigm shift. Previously I thought,"Magnesium, nah, its soft and burns... ." But it won't burn in a vacuum and it won't even catch that easy in air unless it is powdered or fine parts are being machined.

Magnesium is the lightest of the engineering metals with a density of only 1.74 g/cm^3. However, used as a structural metal in an alloyed form, most magnesium alloys have a density a bit higher.

has great strength to weight ratio and it is used for many products like auto body parts, wheels, engine parts, gear boxes, sports equipment, for which light weight is an advantage. Baseball catchers' masks, skis, race cars, and horseshoes are made with magnesium alloys. Consumer goods such as ladders, portable tools, electronic equipment, binoculars, cameras, furniture, and luggage also benefit from magnesium's low weight, and other applications make use of its ability to absorb vibration. Anyhow, Mg can be welded despite its low mp and lasers with their low heat input are very good for welding Mg although porosity can be a problem.

Sometimes Mg is better than Al or steel because of its hi strength to wt ratio. So now I am thinking that all that stuff we might make of Aluminum on the Moon like RR cars, rocket ships, ground vehicle frames and cabins, garage space frames, etc., could be made of Mg instead. Magnesium can be extracted with substances common on the Moon by silicothermic reduction, but Al requires H_2SO_4, carbon and chlorine, substances that are not too common on the Moon- unless something like Dr. Schubert's all -isotope separator which is sort of a giant mass spec or an e-beam and colusius columns can get Al. We will still need Aluminum for electrical wires, given that copper is present on the Moon only in trace amounts, but wiring doesn't add up to too much mass.

Magnesium is pretty interesting stuff. From "Metallurgy Fundamentals" by Daniel Brandt, 2005, we read on page 267:

> "Magnesium is a very light metal used for small parts and many applications requiring low density and corrosion resistance. It has a high strength to weight ratio making it comparable in strength to aluminum and some alloy steels."

It has low density but is also less ductile than many metals. It is alloyed with small amounts of aluminum, zinc and zirconium to strengthen it.

On page 268 we read that magnesium is good for wheels but because of its low ductility it should never be struck with a tool because it can be chipped and ruined. We also read that it can't be strengthened by cold working but can be strengthened by alloying with aluminum, zinc and calcium. Well, calcium is abundant in the Moon's highland regions. Magnesium can be cast, extruded and hot rolled, then machined to final shape.

On page 269 we read about the fire hazards of machining magnesium and that water will make burning magnesium fires even worse. CO_2 fire extinguishers are no good either. Only special class D fire extinguishers can be used on magnesium fires. On the Moon we could machine magnesium in the free vacuum or in inert gas filled chambers, so this won't be a big problem.

When we consider the strength of metals we must consider the strength to weight ratio. Mg is so light that we can make parts thicker thus stronger without being too heavy, especially in the low G of the Moon. Weight will not be as big a problem for architects and engineers on the Moon, but the mass of rotating or reciprocating parts must still be considered, as well as the mass of accelerating vehicles from mining robots to railroad cars.

I think that we will be able to substitute Mg for many things we would ordinarily make of Al like train cars, rocket frames and propellant tanks. We might alloy Mg with Ca, REEs and some Al. Magnesium can be welded despite its low mp and lasers with their low heat input are very good for welding Mg although porosity can be a problem.

The bias towards Al and Ti comes from the fact that we have so many aircraft engineers in the space community. The mechanical engineers want steel, but they will have to do with plain iron and concrete.

Conceivably, you could cut threads in a titanium bolt with lasers, but Ti is hard to extract and cast and upset and weld... so I predict that we will make nuts and bolts of steel. That won't demand too much carbon. David Heck told me that the aluminum frame of the Space Shuttle is bolted together because Al is hard to weld. Steel bolts of course. So perhaps we will be bolting Mg structures together on the Moon.

Here is a good page with photos of the many parts that can be made of magnesium:

http://www.alibaba.com/showroom/Magnesium_Alloy_Parts.html

Also, the tensile strength of wrought iron is 40,000 psi and compression strength is 40,000 psi. Pure iron will have about the same stats. We should be able to produce pure iron with magma electrolysis and an as yet undefined purification step to remove any silicon in it. Iron from fines harvesting contains 5% nickel and will be harder and stronger than pure iron.

The bias towards aluminum and titanium, the favorites of Earth based aerospace engineers must be overcome. We can't make everything out of steel, of which 95% of all metal made on Earth consists, on the Moon, but we will need it for special applications.

I suspect that all kinds of new uses for pure iron and magnesium will be found or invented on the Moon.

Lunar magnesium tech might be applied on or under the ice of Europa someday.

[See: "Magnesium - Workhorse Metal for Europa" by Peter Kokh, MMM #118, September 1998, page 8, republished in MMM Classics #12 pp. 61-62]

http://www.lunar-reclamation.org/papers/europa_outpost_paper.htm#mg_europa

PROPERTIES OF PURE MG (PARTIAL LIST)

- Atomic number 12
- Atomic weight 24.31
- Color silvery gray
- Density 1.74 g.cm
- Melts at 650°C, 1202°F
- Boils at 1103°C, 2017°F
- Valence states Mg^{2+}

Settlements in Space
Compared to those on
Rocky World Surfaces

"Different Strokes for Different Folks"

By Peter Kokh kokhmmm@aol.com

The Vision

The O'Neill vision of very large free-orbiting space settlements,, exemplifying the best of suburban and exurban architecture is an appealing one. Comfort, convenience, access to everything one might need was the promise.

Notably absent are the rough edges and hard struggle of those who might choose to pioneer existing lunar and planetary surfaces that would be stark and barren by terrestrial standards.

Granted, both types of environments face the challenge of creating sustainable mini-biospheres with ever-fresh air and ever-sweet water.

Frequently mentioned is that those bound for space settlements would enjoy familiar "earth-normal" gravity, while those that choose to live on the Moon of Mars or, even worse, on the asteroids, would have to deal with the expected physiological deterioration that comes from prolonged stays in sub-normal gravity levels.

In the O'Neill scenario, space settlementarians were guaranteed the highest standards of living from income earned in production of Solar Power Satellites, whereas surface-rats would be hard put to eke out sustenance from sales of raw materials.

Unexamined: Building and Manufacturing Materials

Both economies will be able to pay for higher quality Earth-produced goods only from the sale of products made from a shorter list of building and manufacturing materials that can be produced, at first from lunar regolith soils alone, then eventually from asteroidal materials. To the extent that this is so, both frontiers will tend to look and feel very similar. Goods and products will be less sophisticated than those on Earth, unless those living in the artificial-gravity environments are much more successful traders than their cousins on rocky world surfaces.

If the colonial policy of taking from "the colonies" only unimproved products is followed, while exporting to Earth value-added products, and if pioneers on rocky world surfaces are somehow prevented from exporting value-added "transformed" and "improved" products, and allowed to export only raw materials, such a difference in standard of living will indeed be the result. But this great difference in standard of living can only come from this type of 20th century economic imperialism, happily, fast losing its grip on underdeveloped former colonies.

Unexamined: "1-G" as a requirement for health

We are all familiar with the overwhelming experience from many thousands of man-hours spent in "0-G" (or "Micro-G" to nit-pick) that muscle-tone and physiology in general degrades over time. The non-sequitur conclusion, however, that this will necessarily be the case for those spending equally long stays on the Moon or Mars is in need of a second look.

1. Will physiological deterioration proceed *as fast* for those on the Moon or Mars experiencing 1/6th and 3/8th gravity?
2. Or will the deterioration proceed at a slower rate on the Moon, and at a still slower rate for those on Mars?
3. Will this deterioration halt at an acceptable plateau level for those on Mars, and at a lower but still manageable level on the Moon?

To make the absolute unexamined and intellectualy lazy prediction that lunar and Martian pioneers will face the same unsustainable fate as those in Earth orbit, demonstrates an unexamined bias that those who hold it *want to hold over the head of those who would be so dense as not to see the very great advantages of in-space settlements.*

In fact, no one having spent more than a few days on the Moon, we have no confirmation of this dogmatic assertion. In actuality, our experience on the Moon has been rather minimal. No one has slept *lying down* on the Moon. No one has walked, much less run, on the Moon *without a space suit.*

Without real evidence one way or another, it would seem to be the honest thing to suspend judgment until we have data from persons spending long times in 1/6th or 3/8th gravity in reasonable living conditions.

Indeed, if either or both 1/6th and 3/8th gravity proves sufficient to maintain an acceptable level of physiological health, then those who would build in-space settlements will stand to gain as well. How?

In comparison to anything else we have ever built, from the largest cruise ship or oil tanker to the largest dam, structures such as a 1km wide Torus (Island 2) or "Sunflower Cylinder" (Island 3) are dauntingly large, for one reason. Coriolis forces, which can induce dizziness, would seem to advise against spin rates greater than 1 rpm, and that translates into a wider radius/diameter to produce 1.0 Earth-normal gravity. The surface area expands by the square, and the structural mass by the cube. If either or both 1/6th g or 3/8th g proves livable, then the construction threshold for such in-space settlements comes down dramatically. And that would make them much more realistic, and near-term, less 22nd Century of beyond.

In essence, while branding everyone who would prefer a rocky world surface as a living environment as a "planetary chauvinist" those who do so exhibit a less than fully examined "1-G chauvinism."

Why pick one settlement type over another?

Instead of looking down on one another, those who can better envision themselves in an in-space settlement than in an on-surface settlement – *and vice versa* – should listen to one another's points. Some may wish to switch "sides." Others may become even more convinced that one of the options is for them. But the end result would be mutual understanding and respect.

From an in-space settler point of view:

An in-space settlement is of fixed size and easier to plan as a whole, with urban, residential, and agricultural planning carefully worked out for best land use and most pleasant living standards. Planning makes the difference. A high standard of living is promised. On the other hand, surface-rats have to deal with the unpleasant traits of their chosen rocky surface world: dust everywhere, unpleasant climates, unbreathable atmosphere if any at all. The prospects of forever living in a struggling frontier town with life therein having a lot of rough edges and too much hard work.

From a rocky surface settler point of view:

An in-space settlement may have beautiful parks and pastoral streams, but they are all artificial. The rocks and "mountain"-lets are zoo-type artificial constructs, not something that resulted from natural processes. There is a difference in biological beauty and geological awe on Earth. That duality won't exist on an in-space settlement, wherein all the beauty will be man-made.

Rocky surface dwellers may be able to look up at the stars and wonder. On in-space settlements, the heavens will zip by at 360° per minute, not a pace for enjoyment. One has to climb to the axial core, and then despin.

It will be a harder road, but all the more satisfying for having trodden it, to reach the point of being truly "at home" on a rocky-surface world than in a planned in-space community. One requires pioneering which builds character and soul; the other does not.

But each of us is at different points in our life and each of us needs something different to feel fulfilled and happy. It makes no sense to put one another down. If those who would settle in-space planned communities need to bash those with other needs, that is not good.

Settlement vs. World

In a previous article, we tried to define "world" as experienced (not in the astronomical sense) as a continuity of horizons, not all of which can be seen from any one location. In this sense, neither the Island One Bernalsphere, nor the Island Three O'Neill Sunfower Cylinder, are "world-like." On entering, one gets an overwhelming picture-postcard view. But along with Peggy Lee, they must then wonder, "Is that all there is?"

Those entering a Torus world let can only see a third of it, an improvement. But here on Earth, no one, not even from the tallest mountain peak, can see but one tiny corner, one tiny pocket of our world.

On rocky-surface worlds, any one settlement may be "all there is" temporarily, but there will in time be many more, each unique, each a place to get away from it all for a vacation break.

He, she, or they who came up with the trio of space settlement designs based on the trio of "only known Cassini curves" conveniently overlook *something nature was smart enough to discover:* the **double helix** which is produced when the dumbbell does not just rotate in one plane to produce the torus, but it also moves along the axis of its rotation. Inside an unfixed extendable double helix settlement, one begins to experience sense of world in which one glimpse only reveals a small part of itself. We have suggested a triple helix design to allow everyone to work on three shifts, staggered eight hours apart, so that each person can work his or her "dayshift" while maintaining facilities and equipment that for highest economic efficiency are run around the clock: "24/7." Such a design direction will, we admit, not allow an easy solution for sunshine access, and perhaps a design competition to work out solutions that are elegantly simple for the poorly thought out classic in-space settlement designs.

Those who choose rocky-surface locations will face the greater challenge in learning to be "at home." But, harder work can be rewarded with greater satisfaction. One sees seniors financially able to choose, make different choices: all senior planned communities devoid of children, devoid of problems, and others equally able to choose, decide to continue living in multi-generational and multi-cultural settings. To each his/her/their own.

Moving off-Earth

Let us respect one another. It should not be necessary to bash another group to reassure oneself that one's own group's choices are correct. Yet we do that all the time in rendering political, social, religious, cultural, and other judgments.

There are enough of us to fill all the varied kinds of off-Earth settlements that we can imagine. Let's not look down on one another or insist everyone be like us and think like us.

To many, in-space settlements alone make the prospect of moving off-Earth palatable. To others, in-space settlements are as unnatural and "zoo-like" as possible. As a species, we would be much less interesting if we all felt the same way.

How much land?

Add up the surfaces of Mars, the Moon, the large moons of Jupiter, Saturn etc. – their surface totals are insignificant to the combined interior surfaces of millions of in-space settlements. If we need to find ever more living space because we continue to fail to breed without checks, then, of course, the overwhelming percentage of human generations yet un-born will live in in-space settlements. But from the viewpoint of those unwilling to be so tamed, learning the hard way to come to terms with rocky worlds far less friendly than Earth, will be the more rewarding lot. And have we not already learned that here on Earth? Our home world was once just part, not all, of Africa. Every pioneer has chosen to leave a place where life was comfortable, for the challenge of settling a new environment in which at first life would be much harder because of all the adjustments to be made. Pioneers leave because they know that the struggle will be rewarding in life-meaning, if not in ease of life-style.

If humans bifurcate, which group will pioneer what?

It is hard to imagine children raised in and in-space worldlet setting out to pioneer a new rocky-world setting. Some children raised in rocky-surface settlements may be won over to the "cushy" side, but others, forged of stronger stuff, will pioneer new and more challenging rocky-world settings. Will there become two branches of humanity? Perhaps, and most likely, each will look down on the other, and that's too bad. Traditional surface-dwellers are pre-destined to be the minority, and in their own eyes, the more fortunate.

But, as a lover of mountains, mountain lakes, and waterfalls, of endlessly variable settings, of star-studded heavens that turn on a 24-hr clock, as one who treasures the experiences of "roughing it," who would rather die from violence in the "hood" than spend one second in a gated community, I say "vive la difference!" **<PK>**

Reading from Past issues of Moon Miners' Manifesto

#11 DEC '87 – Colonist Quiz; Space Oases: 1st Locations; "Internal Bearings"; Space Oases & Lunar Culture; "Space Oases, The Moon & Different Drums.

#12 FEB '88 –" Space Oases: Static Design Traps;" "Space Oases; A "Biodynamic Masterplan"

#13 MAR '88 "Space Oases: Back at Square One – Baby Steps with Artificial Gravity" n "Reinventing Space Oases" www.lunar-reclamation.org/papers/reinv_so.htm

and in MMM Classics #2 pp, 1-15

It's Not Getting Done!

#1 The Big Picture

By Martha Adams - mhada@verizon.net

\ If you are writing a one-paragraph work order or starting up a five-acre industrial complex, you need a Big Picture of what you're up to. What is your objective and how do you think you will reach it? At least time, money and risk cost? The Big Picture is not a rigidly defined machine, a piston-rod-crankshaft assembly. It's more of a pipeline, where the list of intermediate objectives is malleable and only the end objective is well defined.

Where the pipeline is not in evidence and the end objective is vague and elastic, that's a strong warning that it's not real. That it's PR or make-work. *With no objective nor any plan to get there, it's going nowhere.*

These 'Not Getting Done' pieces grow out of my own Big Picture of what needs doing to build off-Terra settlements. To get from here today to there *asap*. As I develop the following pages, I point to critical needs NASA seems to not have heard of, and to how a group of dedicated space settlements workers might come together and *build those settlements* we so very much need Out There.

There is no good reason today why a first generation of human Martians isn't growing up on Mars now. Or off-Terra somewhere else today, like an Aldrin cycler. We need to do something about that. It is the largest and most serious problem facing our human reality today. We need to respond soon, because we risk responding too late.

I'll open with, why space settlements? At any time?

Because there's change coming. It's seductive to imagine our local Terra is a fine place for us all (if we can work out a few differences) and it will stay good into the indefinitely far future. That's not so! It is false because ongoing social / political process right here on Terra makes it not so. (Watch out for the closely related *climate change* now well started.) It is false because astronomical science shows us the violent character of our universe and that sooner or later, some of that violence will come to call. Here.

My second Big Picture point follows immediately from my first. A change, the Big One, will happen at some *point in time*. We have a hard deadline out there somewhere. Never mind the soft deadlines that come up in the news from time to time. This Big One is different. It changes our Terra beyond recognition. Some of us may survive that Big One and we can still live here, if we're lucky; but we can't count on that. We don't know what this Big One is; we don't know when it is. But thru science and rational thinking, we know it's out there in our local Terran future.

(Related comment, not amusing: "The reason the dinosaurs aren't here today, is they didn't have a space program." -- Jerry Pournelle, science fiction author.)

In fact, our deadline doesn't need even to be particularly catastrophic. Anyone who has lived on a farm can tell you what small seasonal variations can do to the farm's work and life. (A single hard hail storm comes to mind.) Much bigger than that can happen. I mentioned climate change. How stable are our world social and economics systems against such disruption? (Current events and recent historical research seem to show us, not very stable.) The big question around this topic is, if our Terran economic systems fall into chaos, can we build them up again? There are those who say, whatever our world becomes in the future, our ability to reach space will not stay with us if we fail to use it to large effect. (Use it or lose it.)

My third Big Picture point is, PR announcements don't reflect reality. They reflect someone's business choice of pretty pictures and nice words to improve their political environment and business climate a little. They sell a sweet reality, nice to accept. Thus the useful news in PR is generally indirect there. (The careful PR reader may discern significant news in what's omitted from the PR.) The news is under the surface and the reader finds it by careful testing against her personal Big Picture.

My final Big Picture point is, beware the apparently meaningful question, "What is space for?" Misunderstood, it can be put to service as an argument *against* human settlements off-Terra. Misunderstood, it supports endless philosophizing with no action ever.

In fact, all space out there, this universe, has no implicit purpose. Our Terran sky is not provided for our edification, instruction, or to provoke a vague and oceanic awe. No supernatural deity placed the whole rest of the universe out there for some immense and inconceivable objective with us, children of men, central to it. A random accident happened. The accident is us and if there is to be any meaning to this, we must make it ourselves.

As humans, we can find a purpose for our local Solar System. Like an empty field is completely changed by placing a house on it, space with people in it is completely different from space as a topic for abstract astronomy and cosmology researches. As soon as people are there, "What is space for?" acquires a very simple answer. *Space is for people.* Obviously!

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It's Not Getting Done!

#2 Long-term Analog Settlements

By Martha Adams - mhada@verizon.net

If NASA has a program to build off-Terra settlements and an economics and trade system to support them and their growth, then where is their research and engineering to do this? *Space is hard.* Where are they making ready for it?

We can't go out to space to learn how to live in space. The space environment is too hard to reach and too demanding once we're there, for us to hop out there and play around. To learn something about the human meaning of the space environment that fills most of our universe, link over to

http://www.geoffreylandis.com/vacuum.html.

(Note interesting and useful further links there.)

As you're reading Landis, notice especially that if you find yourself suddenly in a space environment, you have some 5-10 *seconds* of useful consciousness to do something to save yourself; but if someone else comes along and brings you back into a lifespace within about a minute, you probably survive. You can see that off Terra, you're not going to dash out in your shirtsleeves, run over to your neighbors place, knock on the (airlock) door, and enter once it opens. There is also the matter of local and cosmic radiation.

And *this* is better than living on Terra? It's a good topic for anyone to work on who thinks about space. For many modern Americans, no, it's not better than living on Terra. But even today, America yet has pioneer people who can get along just fine without a soft and easy life, if America today seems largely dedicated to suppressing divergence from a quiet ...norm. And, anything out there off-Terra could be a whole lot better than Terra becomes, after some local or astronomical event as I've mentioned elsewhere in Adra. (Some may point also to rapidly evolving computer-based social-control technologies. Ref: China; George Orwell; Cory Doctorow.)

So coming generations really could live and work out there? Yes, provided a few of us make that happen. Which begins with a detail we take for granted here on Terra: lifespaces. Off Terra, nobody goes anywhere without a lifespace. Maybe a tiny one, like a spacesuit; maybe, someday, as large a lifespace as a "generation ship".

But, you may reasonably say, how do we build lifespaces? (Glad you asked.) We do it by thinking and research and engineering. By recalling related experience: aircraft, submarines, diving and high-altitude suits. By everything from simple lab work to complete studies in effigy. By building and operating *analog settlements* to establish realistic ranges for a host of parameters and practical details. Such research and engineering can look like a game and in fact, serious gaming is a part of the work.

Analog settlements are how we learn to live in space while we are still here on Terra. Serious work on this topic has been done already -- Biosphere 2 and Robert Zubrin's analog Mars missions come to mind. But much remains to be done and anyone working at space settlements, wants to attend to who is doing what.

I suggest that for best return from the following, you want to break off and go now to this Biosphere 2 site: http://en.wikipedia.org/wiki/Biosphere_2. Read it and visit two or three of the links provided there. Then come back here, having just acquired a birds-eye view of how large analog settlements projects can be hard to do.

I think this over-view shows why such work is not much in the news: it's difficult, it's slow, it's not exciting, a good outcome is not guaranteed; and it eats up time and money. As people live for months or years in a limited environment (like a prison, in fact), it hardly generates the excitement and conflict the news media want. Except if something goes very wrong, of course. Yet whatever the work or nuisance to do these analog settlements projects, it's clear that whoever would go out to space *must* do them. First. We must do our research and engineering first and do it here; and then do our space settlements asap next.

Nobody is above these basics I've just pointed out. Thus we can look at what NASA is doing, and we see something central missing from their program. A gaping hole there. Where is the analog settlements work?

When NASA started their Great New Program to repeat Apollo (with improvements, the PR says), I asked, where is this getting us? I'm still asking that, because, this Great New Program seems to carry, behind its fanfare, some serious issues. Namely:

1) it's slow and runs over long time. This makes the Program terribly vulnerable to political meddling, adjustments, and "earmarks."
2) It speaks of revisiting Luna (About time!) and even of bases there, but it fails to address the extended future that is (if we choose it) out there.
3) Someone else could easily leapfrog and surpass such a weak and slow program; thus we may eventually arrive ...somewhere, to find a "greeting" committee already there. And, of course,
4) just in case NASA or someone else is doing the needed settlements studies, *where is this work happening?* Without this, all else amounts to nothing? It's a really interesting question: remember the Lockheed Skunk Works? Some people like to seek out and analyze small news details to find large secret programs. I haven't heard any of them are finding anything of this, which makes a strong case there's nothing there to find.

Well, maybe other countries are working at space settlements? Where, or in what countries are they doing serious analog settlements research and we aren't hearing about it?

One finds in the news that Washington's programs are basically "what Americans want." Assuming this for the moment, we come to interesting questions. Why do "Americans want" senseless and expensive wars? Which drain America's resources off the top and return nothing? Why are Americans opposed to spending "large" amounts of money (as much as 10% of a war cost) on space, which offers the greatest returns of any option in sight? (Imagine the year is 1500 AD and "What is *America* for?") But that goes off-topic here: I want to talk about *settlements* in space.

As I write, today, "Settlements in space" is basically a getting-off-zero problem. It's new, sort-of. (We had it almost entire, fifty years ago.) Nobody ever did that before, nor anything much like it (except Apollo). Yet if the objective is resolved into its major parts, none of those are new. They are generally the application in a different environment of basics commonly known to students in good high schools. That is, *to children.* It's only when you put those old basics into a space environment, that the "settlements in space" problem acquires some appearance of imposing magnitude. (Helped along by the practical challenge of *getting there,* which is actually a different test entirely.)

The problem is both simplified and made more difficult by the practical necessity of lifespaces. Off Terra, if you're alive, you're in a lifespace. However, for millions of years past, we've lived in the open outdoors of Terra. Across all our species evolution, nobody ever lived permanently in sealed lifespaces. Now comes change, and we'll have to adapt our lives, our culture, and eventually our physical selves, to live with this new reality of sealed lifespaces within a large and totally hostile environment. I expect this will prove to be a hard requirement to meet. (But our fishy ancestors did it! They came up onto dry land out of Terra's primeval ocean, and they did it without our technology. Space is the same basic challenge. I think "evolution" takes on a new meaning here. Today, we can do space.)

But today, I see no NASA analog settlements program. To do space, we must learn how first. We'll have to mock it up and work it out, right here, long term analog settlements, to learn the operational principles in appropriate context. Robert Zubrin and Mars Society have been doing analog Mars settlements. Biosphere 2 tried a large ecological system experiment. *Much* more is needed, and whoever talks of space settlements isn't serious about their topic until they are seen making ready for what they say they're going to do. *Someone* must run several analog space settlements over time: at least one of these must run five years, at a guess. Including study of culture issues and the social psychology of such closed environments. Can NASA do that?

Since as big slow projects go it's just not that large a challenge, I believe that yes, NASA can. If they will, is something else. For whatever practical reasons, NASA's feet are firmly glued to Terra's surface, and their programs seem designed to keep it that way. I foresee that someone else must do that basic work and then progress to space settlements. There is a simple program and progress indicator: at least three long-term analog space settlements because one won't be enough. And it wants to *start now.*

*[Editor: Note that NASA **is** involved in the H**aughton Mars Project** on Devon Island, at a site about one kilometer from the Mars Society's Flashline Mars Arctic Research Station. Other partners in HMP are Canada and The Mars Institute.]*

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It's Not Getting Done!

#3 Economics Gaming

By Martha Adams - mhada@verizon.net

Off-Terran business economics will prove another hard challenge after the lifespace and social issues studied in the analog settlements projects. I see two reasons for this. The business economics of space settlements must extend far in space and among many concerned people and institutions. And extend far in time. And over the long run, a business economics that works is as necessary to life off-Terra as the air and water in the lifespaces. It is a central part of what the people who are there do there; and it pays the costs of Settlement operation and growth.

How will business economics work in space? Some details will certainly be very different from local experience here on Terra. History provides useful parallels. A few centuries ago, business people could wait months or years for business to complete that they had started. (Giving us today's expression, "My ship came in!") It does make a difference that today, business parties across the solar system can communicate with lags up to a few tens of minutes, but manufacturing and shipping hardware and materials across space seems likely to require years of time. History's useful parallels, won't be answers.

We can't afford put out a few settlements and speculate as to their eventual economics. Before we put our space settlements out there, we'll need to study how business economics probably works there. That study, and testing, must start at least as early as our first work on longterm analog settlements. Its results will certainly bear upon site choices. We must understand early-on what the basic economics will approximately be for each particular settlement. I expect the early work of space settlements to include serious economics modeling and gaming to study this new field of business and economics in space. (Which carries a risk. An old hippie saying goes, "Where all think alike, none think much." Here, it's a warning to the small space settlements community that this work, so like gaming, risks having too few people and a single closed group doing the work.)

I think here is where those who advocate just one settlement for starters, go severely wrong. Three settlements might be a practical minimum. I expect this topic to develop over time about the usual way: cycles of trial and error, supported by theory in its present state; cycles of assessing what was learned. Such work, done in effigy, won't cost as much as the analog settlements projects, although it's equally as necessary. It can be set up by knowledgeable people as computer games. (For an old and limited traditional game, think 'Monopoly'.) To see reasons not to try this first for real out in space, see today's American economy.

Over historical time, you see a lot of trial and error in Terran economics. As I write, one might mention today's American economy in particular. In this trial and error, if something crashes, well, someone takes a beating. I look for economics in space to work different from this, because space is a seriously hostile environment.

Whoever intends to face this large business ecology challenge, is working at it now. In those wonderful NASA programs, I don't see that. The reasonable belief from what's visible out there is that *NASA's feet are firmly glued to Terra's surface, and they're going to keep it that way.*

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It's Not Getting Done!

#4 Hardware

By Martha Adams - mhada@verizon.net

There's a risk for any organization that it freezes into working at some subtopic and after that, it goes nowhere. For instance, it might degenerate into an organization for mutual social backscratching and classy costly banquets. Here, there's a risk the space settlement organization falls into indefinitely extended planning and research. For this reason, the organization wants people in it whose lives and objectives focus on getting those habs out there now.

Namely, people whose lives are about development models; about hardware to ship off Terra and others will live their lives in it and if someone isn't ready now then they want to set trivia aside and hop to it immediately. This is not a place for party people. A Settlements project requires hard-driving managers who refuse diversion from the work at hand.

Artists may offer such diversion. Any engineering work wants artists. Nicely done artwork and videos that illustrate program objectives as if they are complete through to (successful) reality can immensely help the workers get there. However, art also makes nice entertainment. If you're on vacation, why not sit back and enjoy the pictures? If you're not sure of your engineering, why not sit back and enjoy the pictures?

Which makes good art a risk. The best art is not the hardware it pictures. Sitting back to watch nice pictures won't bring any hardware to reality a minute sooner. The future you want only exists after you build it. The organization pulled together, the money in hand, the Terran industrial base starting to work, the problem is habs, lifespaces and their support systems, and where to put them. The sooner the better, and it's going to be a lot of hardware. Let's think about making hardware.

Each young engineer who begins in the work, passes through a small crisis. The crisis is, to cope with the risk of building the hardware. Plans on paper or in a computer system, are malleable and (relatively) inexpensive. Hardware is commitment and answering to the guys with big money. Not everyone can do it. Thus not all with an engineering education are engineers. As work moves along from the idea of space settlements, to the fact of hardware to be shipped off-Terra, this commitment is one of the big risks along the way.

I wonder if this has something to do with NASA's failure to go anywhere over several decades since Apollo? To do something? ...Interesting, but off-topic.

Today's NASA machinery that so nearly copies the Apollo machinery of fifty years ago, is called "progress." Well, it redevelops some of the know-how we lost when Apollo was killed. There might be good in that. But it's not serious movement toward building real live space settlements.

Starting to build hardware will be a beginning, not an end. The work can move quickly to a production line and near mass production. Thus the cost of building settlement cores drops. Which calls for each unit that is produced, to be as like as possible to its predecessor and to its next. Which idea in its application tells us, if we're going to do an initial production run of six settlements, they are going to be a lot alike.

I think this example makes my point. We step away from the idea of building many settlements not one, because it's necessary. We step away from the idea our settlements are all different because they go into slightly different places, because they really aren't so very different at all and we need the economy of (as near as we can get to) mass production.

Meanwhile, back in Washington DC, there are a few practical problems:

- ITAR,
- The thinking it codifies,
- The people who think like that.

And as history shows, for whatever reason, Washington wants to make wars, not space settlements. Seeds for the next war are visible today. After wars, there's not much money for anything like space settlements. Which leads me to believe, humans in space is not going to grow very much until there are enough humans in space to develop economics not locked to what Washington does, and this won't develop in a hurry.

For now, in the perception of most people, "space is NASA." And I cannot believe NASA is going to do space settlements. Their feet are too firmly glued to Terra's surface, and they're going to keep it that way.

[Editor: *Stay tuned for next month's Power Conclusion* as Martha Adams takes up the topic of **The Future**.}

Martha Adams has been a Moon Society a little over a year, and lives in Quincy, MA, a suburb of Boston. We met her in person, recently, at ISDC 2009 in Orlando. <**MMM**>

Playing with Modular Designs for the MoonMars Atacama Research Station

By Peter Kokh, Member Advisory Team

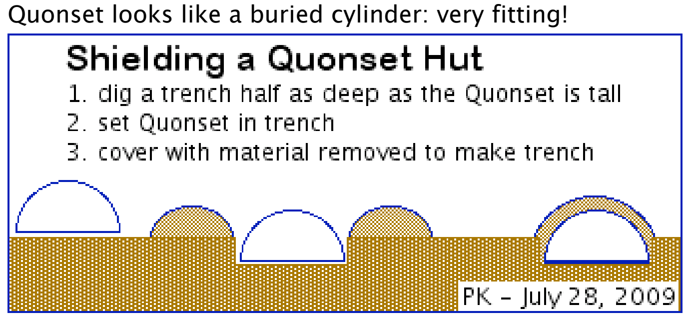
For those readers familiar with the appearance of the Mars Desert and Mars Arctic Research Stations, the shape of MMARS in the Atacama Desert of northern Chile near the Inca de Oro Observatory, will be quite a departure. Starting with a suggestion from Don Foutz, handyman extraordinaire and jack-of-all-trades on call 24-7 for MDRS emergencies from nearby Hanksville. To keep costs down, Don suggested using the wingless fuselage of a large surplus aircraft.

The Chilean Air Force, who is very much behind the MMARS effort, took the hint. They had two surplus Hercules C130B Cargo planes. Actually, that shape is close to one of the proposed Mars landing craft, and the basis for Mars Society Australia's Mars-Oz analog station design. But as big as a C130B might seem, its one floor has less square footage than the MDRS "double tuna can." And that, as far as we are concerned, is perfect*!*

MDRS has from the start begged for expansion with modular additions. Too many incompatible functions are forced into the same space when they should be mutually isolated. Suggested expansions go nowhere.

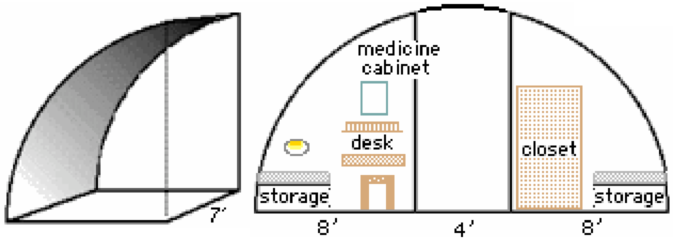
We'll put the Command Center in the C130B with Communications, Computer Work Stations, EVA Capcom, Mission Capcom and other similar functions inside its 42' long, 10' wide, 9' high cargo hold.

Lower the tail ramp and enter a series of hallways (10' wide semi-trailer beds may do, with room for storage lockers on one side, photos and art on the other). These lead to a trio of 20' wide, 60' long Quonset huts. They will be set in trenches then covered (shielded) with the material excavated to make the trenches: this will help maintain benign internal temperatures. A buried Quonset looks like a buried cylinder: very fitting!



A Quonset of this size is an inexpensive choice. We could have bought a dozen for the price paid to fabricate the MDRS hull (in both cases, prior to outfitting.)

- **The Crew Quonset** will have a dozen "state-rooms", showers, urinals, and a Quiet Lounge. [top next page]

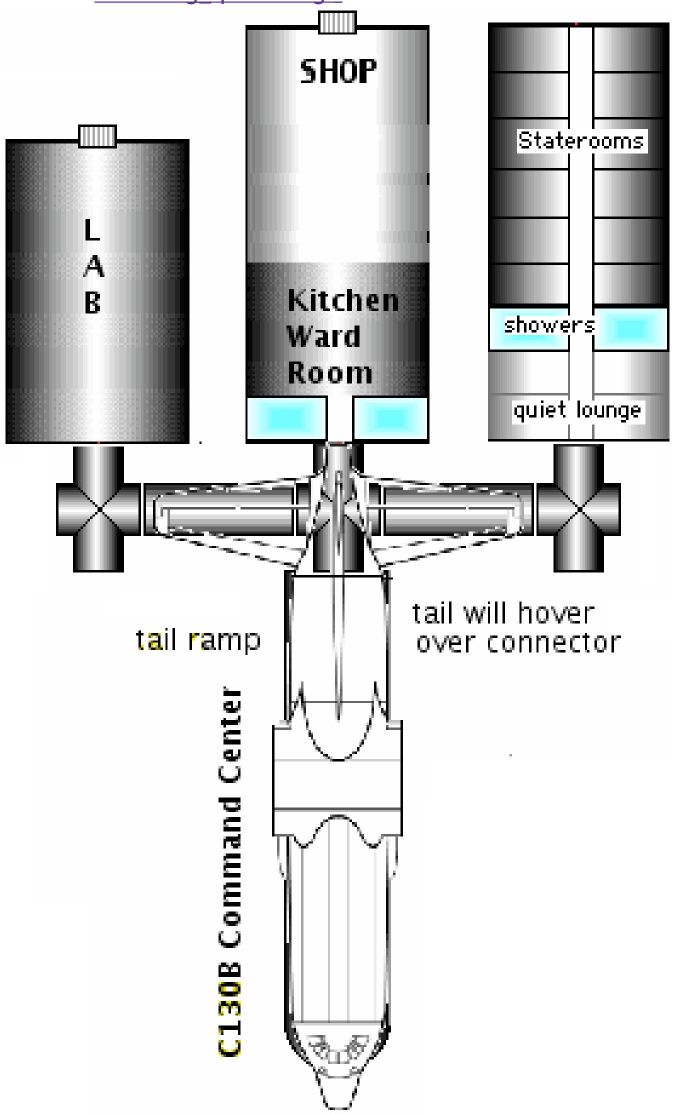


- **The Science Lab Quonset** will provide spacious, well-equipped Lab space with plenty of storage for geological and biological samples as well as equipment.
- A third will house the **Workshop**, repair and fabrication area towards the rear, and the **Kitchen, pantry and ward room** (dining) to the front – well separated, of course. This unit will also have **the toilets**.

To see the illustrations, go to our MMARS Google Groups site: http://groups.google.com/group/moonmars

On the right hand side, click on files. Look for the following:

20'x50'QuonsetCrewModule.gif
OperationalPhase.gif
shielding_quonset.gif



Now, when and if MMARS is built, it may look quite different from these sketches. But we are still playing with concepts that seem appropriate for the situation. Our team has a wealth of capable persons with a wide set of expertise. So the interplay of ideas is good.

It is one thing to come with a neat design. We have to find a combination of ready-to-adapt structures and easy-to-install outfitting elements. If we have everything designed down to the last rivet, the team will assemble in February at the Santiago International Airport to put together the C130B Command Center, which will then go on display at the 2010 International Air & Space Show (FIDAE) there in March. If you are realistic, you will realize that a lot could go wrong. That's why our MMARS team is working hard to come up with not just the neatest solutions, but with the cheapest and easiest to assemble. We'll have a Chilean team of a few dozen workers at our disposal, but unless we are fully organized, and all our material needs are delivered on time, a disappointing result is quite possible.

The Moon/Mars Atacama Research Station has one thing going for it, Chilean Air Force determination to see it built and become fully operational as the showcase of Chile's contribution to brainstorming how open-ended expandable outposts can work on Moon and Mars. We are delighted, of course, that the General in charge of this project explicitly requested Moon Society involvement. It give us an ideal opportunity to further develop and test out concepts that we have been playing with for our own Lunar Analog Research Station, a project that the National Space Society has indicated a willingness to co-sponsor.

The site has been narrowed down to an area that is largely free of vegetation, and has coloration that in some places looks lunar (grays and whites) and in other places reminds one of Mars (tans and ochers). The back-drop is doubly spectacular: the Andes to one side, and some of the darkest night skies in the world above.

The nearest major city is Copiapo (accent on the final o) with some 200,000 people. The people there and in other neighboring towns are excited about the project, as a visitors center will be included along with a wide range of public and student outreach activities. Some of this is already in place in association with what is now the world's largest concentration of World-Class observatories, surpassing both Kit Peak and Mauna Kea.

The educational outreach program is run by TATA, The Astronaut Teacher Alliance based in San Diego. http://www.spaceportacademy.org/tata If the association with Chile seems strange, is is the result of a

CA-Chile agreement signed by Gov. Schwarzeneger! ###

Extracting Minor Elements From Moondust

Titanium, Sodium, Chromium, Manganese, Potassium, Phosphorus

By Dave Dietzler pioneer137@yahoo.com

Elements present in small amounts by weight percent:

In **lunar mare regolith**:

titanium 3.1	sodium 0.29	chromium 0.26,
manganese 0.17	potassium 0.11	phosphorus 0.066

In highland regolith:

titanium 0.31	sodium 0.31	chromium 0.085
potassium 0.08	manganese 0.0675	phosphorus 0.05

We can see that the concentrations of sodium, potassium and phosphorus are about the same in both types of regolith. As for titanium, chromium and manganese, mare regolith is richer. This is another good reason for basing on a lunar mare coast. The question is, how do we extract these useful elements? I won't go into the extraction and uses of titanium because that is well explained elsewhere. Before discussing possible means of extraction, let's examine the uses of these elements.

Phosphorus is needed for n-type solar panel material. Along with potassium it is one of the three major fertilizer ingredients with nitrogen being the third. Potassium and sodium can be reacted with water to make potassium hydroxide and sodium hydroxide-caustics for soap making by mixing them with vegetable and/or animal fats. Soap will be an essential for humans on the Moon. Sodium is needed to make table salt, another essential for humans, and sodium hydroxide reacted with silica can make sodium silicate, an inorganic adhesive with many uses from painting to binder for sand molds. Sodium could also be used for sodium-sulfur batteries and high-pressure sodium vapor lamps. Sodium oxide is added to silica to make glass with a lower melting point. This makes the glass easier to work. Chromium and manganese can harden steel and give it corrosion resistance. Stainless steel is up to 25% chromium.

{**Editor:** Sodium and Potassium can also be used as dopants to lower the melting point of mare regolith in the making of glass matrix in which to embed glass fiber made from highland regolith. Thus Sodium and Potassium could be critical to production of glass-glass-composites which may become a major building material for solar power satellite components.

Also, sodium silicate and potassium silicate based metal oxide "paints" will be the basis of a new art medium, with alkyd, acrylic, and latex paints being exorbitantly expensive imports. #]

I haven't seen much data on the extraction of these elements from lunar regolith so what follows is hypothetical. When following the scientific method that's where we start. Eventually we will need experimental testing of these hypotheses. Let's begin with potassium and phosphorus. During serial molten silicate electrolysis, these two elements are deoxidized at lower energies than ferrous iron. When extracting iron and oxygen by electrolysis these should boil out of the melt since their boiling points are much lower than the 1300-1600 C. temperature of the melt. They will probably react with the oxygen and form oxides that don't boil until very high temps. Will the oxides be wafted away by the oxygen bubbling from the melt and then be trapped in a condensor/filter or must inert gas like helium or argon be flushed through the furnace to keep them from settling back into the melt? Research is necessary to answer this question.

Sodium is deoxidized at higher energy than iron but lower than silicon. When conducting serial electrolysis after iron removal to get silicon by increasing voltage the sodium should boil out and will probably oxidize, so we have the same situation with sodium as we did with K and Ph.

If we can get these oxides we will then have to reduce them with hydrogen or carbon then use fractional distillation to separate the pure elements. We might want them in salt form so they might be leached in acid, treated with chlorine, passed through ion exchange columns, etc. Additional research is called for.

Manganese and chromium are deoxidized at higher energy than iron but lower than silicon. They have high boiling points and will remain dissolved in silicon as it is extracted. The silicon could be purified without any chemicals perhaps by vacuum distillation and zone refining. The Mn and Cr should be left behind after distillation and could be added directly to steel in mixture or they could be separated chemically. This might involve reacting them with chlorine gas to form salts then leaching away the $MnCl_2$ with ethanol. The salts would then be electrolyzed to get pure metals and recover the chlorine. Ethanol could be made by fermentation of plant products grown on the Moon.

Before closing, let me comment on sulfur, another minor element present at from 540 ppm to 1700 ppm that could be used for everything from sulfuric acid to sulfur cement. Roasting sulfur out of large masses of regolith during volatiles harvesting could lead to the formation of sulfuric acid that would be hard on equipment. My impression is that most of the sulfur is present in troilite, FeS, of meteoric origin. Since this is not magnetically susceptible it might be possible to extract the troilite electrostatically then decompose it with heat or electrolysis. Sulfur will boil off and be trapped in a condensor. **<DD>**

*Data from:
http://www.sps.aero/Key_ComSpace_Articles/LibTech/LIB-006_Lunar_Materials_Utilization.pdf

{**Editor's Note:** Ever since regulations forced industries burning coal to scrub the sulfur from their exhaust, the price of sulfur has plummeted with the result that much experimentation has been done as to how to make use of this newly cheap versatile element.

Sulfur block, sulfur shingles, and other building material products are now on the market. Sulfur can be crystalline or amorphous and even plastic.

One idea we have looked at is liquid sulfur-impregnated fiberglass. Experiments could be done outdoors or in a ventilated basement. What properties would such a composite have? For what uses might this type of composite lend itself?

With common materials such as wood and plastic being unavailable on the Moon except at stellar prices, this is an area that perhaps deserves some careful experimentation. Early favorable results would push this investigation into industry or university labs.

Anyone interested? Be safe and careful! <**MMM**>

[Continued from MMM #227, Parts 1-4]

It's Not Getting Done: #5a

The Future -- ??

By, Martha Adams

When Apollo 11 went up, the future in space looked good. For one thing, the Apollo Program offered a constructive choice and a way out from the Vietnam debacle. We are now several decades into that future and it's something else than hope offered. Today we seem to have jointly two war debacles and an economic debacle, among other matters gone wrong or failed. I hear elements of American stability and life quality compared to a banana republic. I don't see progress there. In brief, I've lived long enough to find myself actually in the future that I once imagined, and I think it's pretty crummy. So I wind up my "It's Not Getting Done" series by outlining some of my observations concerning where this future might go from here.

To look for the future, don't look toward Washington. As described in Robert Winter-Berger's book, *The Washington Payoff* (a must-read, if you haven't already), Washington has its own objectives. The book's reader quickly realizes a space Settlements program will not be one of them.

I hope some of us will find ways to make this existing situation less grim than it appears. I regret the immense national cash flow into Washington goes ...where it goes; but let's act from what reality is, rather than sit around swapping regrets about what reality could be. To look for the future, look up toward space. Given money; our young peoples remarkable capacity for accomplishment; good leadership; and a few years of time, a space Settlements program with its economic and cultural benefits is only as far away as a lot of work. (That was true in 1970, so why not now?)

Of course, it helps to watch what is, or isn't, in anyone's pipeline. China, Russia, India, America, you name it. The future will not appear, surprise, out of nowhere and no precursor signals. A rabbit out of a hat. In fact, some things must happen before others, and anyone can project a plausible sequence. I've been talking about what must happen before a human culture in space happens. Space is hard but provided the preliminary work is done, it's accessible. (If life were more simple. In reality, there are challenges not about the science and engineering but about money *and*.... See the movie that is out now on DVD: *Orphans of Apollo*. The space community often voices serious angst about Washington's ITAR controls. Whoever thinks about space settlements wants to keep a deadly hierarchy in mind: *Regulation* kills *money* kills *engineering*. For which reason I believe *regulation* may be the showstopper for space settlements, not the science and engineering issues so loudly touted in the news media.)

How much money? *Weigh carefully* what NASA says about costs of space work: it's not necessarily so. Robert Zubrin estimates in his 'The Case for Mars' (1996), that three Settlements missions to Mars could be sent off for around $30 billion in 1990 dollars. Compared to the economic and social costs of today's ongoing wars, or of faith-based money policy in Washington, that's pocket money. Even if over time, it takes more inflation-shrunk dollars to do it. (If you buy your own groceries, you see that inflation now.)

Any thinking about space settlements must recognize the immense practical difference between public money vs private money in action. Go to the current news. Find a few pictures. Compare a SpaceX launch site with the usual Cape Canaveral constructions. There's a large job to do, but maybe the money to do it need not be so large as a NASA follower would guess. In the following sections I explore some related topics I've had on my mind lately:

Leader

Hurtful governmental regulation may be overcome, one way or another. This will not happen by lucky accident nor mere time passing. Sheer need for change may or may not suffice. A core Settlements requirement against obstacles of bureaucracy and basic physics is strong <u>leadership</u>.

I write the following with no particular person in mind. Since I know of several people who partially meet my proposed requirements, I wonder if a small committee could do the job. This question is a can of worms and in the following, I'm going to stay with "leader." (And I'm going to say, "he." In this culture, for this settlements objective, the man has an advantage that will be needed. Also, my text grammar is more simple given this choice. I think that in a nicer world than we have today, a woman is the better choice for this Settlements objective.)

A Settlements Program leader must be charismatic. Have you noticed, a few people stand out in a crowd? Here, it's a job requirement. And he wants a phenomenal memory for names and people; also, a capacity for clear expression of rational thinking. (Compare Bush II vs Obama: no contest.) His age at startup time wants to be in a narrow range of 40 to 50: old enough to have had serious life and business experience, young enough to accomplish a difficult plan and its setbacks over many years.

The Settlements Program leader cannot be a career person who hops from job to job with pay and social status increasing along the way. He must have chosen to devote his life to his objective. He will know "things happen" and set a goal at the top of his list to make himself replaceable. He will have his successor nearby, ready to step into his shoes at need; which need may not be foreseeable! I recall a new hi-tech company that nearly failed after one of its principals took a short business trip by air on 2001 September 11. Things happen!

The Leader person must be a gifted engineer. To appreciate this need, you want some engineering experience yourself. Then you can listen to Elon Musk to hear the richness between the lines as he speaks. A listener without engineering background won't hear how Musk chose between options to settle on what was <u>going to</u> work. I hope to see a Musk autobiography someday because I'll learn a lot from it.

Such ability as Musk brings to his success, is not in the usual run of people. The essential process of the Settlements program is a series of engineering choices. Few people can see the options, make a series of choices in real time, and get them right enough. Musk is notable because he does it. I don't think even a good consensus group could do this. It falls on the Leader. Success is everyone's but the Leader gets the direction right. Else, the Settlements program fails.

Industrial Campus After money and a Leader, the Settlements program needs a place, a location. I have heard "virtual" organizations mentioned in this context. "Virtual" refers to an affiliation over the internet of people far apart over Terra's surface. It won't work.

It will fail because it loses the essential ingre-dient of immediate human personal interaction. Only a "real" organization can carry out this program. And it will require a large place to do it. I envision four engineering campuses (Site; Habs; Power; Business) and a central Offices campus. These five all together as one, each accessible on foot to the others. The old-fashioned way!

Further, the Center being a heavy manufacturing location, it must be placed where the large Settlement structures built there can be moved out to launch location. "Central," here, means the center of the organization, not the center of the country (which I hope is America). Thus as I write, I see the "Central Location" being somewhere south of New York City, probably not as far west as Texas (hurricanes) and directly accessible by water to Cape Canaveral. (And no low bridges.)

I realize this sounds like bricks-and-mortar smokestack industry from the mid 1800's to the mid 1900's. I am not going into a lot of industrial theory here. Firstly, whoever builds such an industrial base today has much more management know-how to work from than anyone did back then, and so can do it better. But secondly, this structure with its strong hierarchical elements, seems to me, most appropriate for a dedi-cated-purpose organization that must accomplish a well defined and difficult objective at minimum cost. "Old-fashioned" is tested, a solid base for a visionary new objective.

This space Settlements objective has a lot of dreams behind it. How the accomplishment in fact, will accommodate practical engineering realities to those dreams, remains to be seen. But I believe that if we don't do this, now, then maybe, nobody will ever. (Or people might do it, whose interests entirely neglect Terra as a whole. Small examples come to mind. Someone is making a huge mint of money selling AK47's and heavier military hardware. In 2009 May, think of Pakistan's collection of about 100 nukes.)

I believe that if we don't do settlements in space, then we're gone. In the immense and violent processes natural to our universe, it's easy come, easy go. If some local cranks don't accomplish it first. And the second reason is, of course, outlined in Winter-Berger's book which I mentioned earlier. Who goes to Washington, and why? I would like to see "national service and the wellness of America" at the root of it. I'd like to see that.

Research and Development

I think that here in America, there has somehow developed a conservative attitude that if we undertake something new, that means change; but change is just too hard to do now. So let's spend that money where it will serve some purpose. (Another war? More corruption?)

One might argue that any boat needs an anchor, so the conservatives do have a point there. However, their point expands too easily into authoritarian and rigid social policy. Fortunately, we yet have people in America who are innovators and ambitious. People who can recognize that off-Terra is accessible to anyone who can do the work to get there. (And find ways past serious bureaucratic obstacles to do it.)

Today we have seen demonstrations that rockets can fly in space without an atmosphere to push against. The demonstration was hardly necessary: Newton wrote the mathematical theory of it going on three centuries ago.

We have seen people go out to space and then return, still quite recognizably human. To go to space and then stay there, makes good sense and the engi-neering to do it is developed today far beyond specula-tion and outline. The cost to do it seems well within parameters set by recent economic adventures to prop-up large financial institutions that had better names than management. (...Has that really changed?)

The people who can do the job are here now. They are our young people. The Apollo people who built the Saturn booster averaged out to about 26 years age. Young people! We have no greater treasure in our human world than these young people, and we have today an appropriate task for them to undertake. And some of them are doing it.

Space-oriented organizations today range from large installations (SpaceX comes to mind), down to informal groups of grad students in rooms full of books and experimental hardware. I'm developing a Links section in Adra so that anyone interested in space settlements work can find others in the field.

I think people working at space, face an occupa-tional hazard. It is the risk to Do Something but what they do isn't directed to need. Lacking focus, they turn their energy to social activities and catered banquets rather than to the work.

It's Not Getting Done: #5b

People! People living in space puts us, the human species, into a new ecological niche. As we do this, we can expect some surprises along the way. Birds that live in the wild are different from their cousins in the barn-yard. Watch some fish that seem entirely comfortable in their environment, and think about how they might get along in a different environment. Humans in space will become different from humans who remain here on Terra, and right now is not too early to be thinking what those differences could be. And about when those differences will ...make a difference.

I expect the differences to be already significant *before* anyone goes out to live in space. We will see this in the long-term analog settlements we must try as we learn how to live in a space environment. In fact, I expect the people who first go out to live in the first off-Terra settlement, will *already* have demonstrated a strong likelihood that they can do it by living several years in an analog settlement.

As I write, I have not yet seen anyone working on this topic of the culture of later human generations living in space. I expect to. It is because the difficult effort to build and place those first settlements, will require it.

Hardware Hardware built to go into space faces the chal-lenge that very many people working together must design good hardware. In fact, this is a difficult chal-lenge. Us humans don't seem to be very good at choo-sing between complexification and appropriate useful design.

For example, look at machines of all sorts that were built within the wartime constraints of WW2. At aircraft and ships; at cars and trucks and buildings. Restraints of time and materials urged the designers to simplicity, relevance, and effectiveness. There is a sparse beauty to those designs which is lost in modern practice, pushed out by an overblown complexity.

Since WW2, design practice has changed. Earlier in Adra I mentioned the old W20 Radiation Laboratory building at MIT which was replaced by ...well, a very different kind of building. In (popular) computer technology one sees the transition from efficient command-line control in computer systems like MIT's ITS and unix to today's "Graphical User Interface" (which gave Microsoft an opportunity for vendor lock-in and DRM additions, and they took it). (The character of their operating systems is why there is no place in critical space systems for Microsoft.)

In space, our designers and engineers will be forced to seek elegant and simple design again, under much harder constraints than seen by WW2 engineers. Some of the machinery must be designed for maintenance by people in spacesuits working through pressurized gloves. Our business and cultural tendency to complexification *cannot go into space*. It's too dangerous; too heavy; too hard to use; too unreliable. The hardware that goes into space; the hardware that is made here to serve there, must be the simplest possible and most robust possible that anyone knows how to make.

Settlements We make space ours by living there. That's simple enough. We need no supernatural permissions, nor interventions to do this: it's straightforward technology. Reasons to do it are compelling enough; the central issues are matters of detail, and that's where the difficulties begin to come in. If we tackle those difficulties directly, they will immediately become smaller and more manageable: we know that, don't we? We know the first most central step to doing something is to say what our objective is, then start working at it.

The key to progress is *settlements*, not indefinitely extended "exploration," which is better done from out in space anyway. We go about getting into space by putting out viable settlements *and* a human economic and business network. Because space is harder than Plymouth or Jamestown or (back in history) Europe and England, we must do this with a little more foresight than served humans here on Terra a few centuries ago. That is what the analog settlements and gaming I've mentioned earlier are all about (if you arrived here in the middle of things and haven't read earlier Adra pages yet)

After all the work that I have outlined above, one opportunity remains for a really serious error. It is, to send out *just one* settlement and then, wait for something good to happen. The initial project to send out the first settlements will operate under severe time, money, and regulation limits. Such limits will encourage a minimalistic approach to the work: beware *too* minimalistic. The perceived need to send out just one settlement, will be intense. That's too risky, and over the longer run, it fails the most basic reality test.

Just as a finger held close to the eye blocks a large visual field, thinking about a single settlement hides the basic that we are up to something here that is very much larger than that. The topic is the emergence of our human species out of our local Terran environment and into the far larger and different environment around our Sol. (A prelude, hopefully, to our reaching much farther out than that.)

Just one settlement somewhere “Out There” won't do it. That's too small and in view of the hard space environment, too risky. We need several Settlements, *and* a whole business, economic, and scientific culture. It is, after all, what we're really up to, isn't it? In the hard environment of space, the central elements of these Settlements will be highly interactive -- and highly supportive, each one of all the others. If we don't get that right to start, we risk not getting it at all. Failure. For which reason, "Settlement" is a wrong term: the reality requires the plural, "*Settlements*", right from the start.

In his *The Case for Mars*, Robert Zubrin describes a plan for sending out consecutive Settlements to Mars that he places within travel distance, one from another. His purpose is to plan against some failure of the travel machinery. Such planning is necessary, but I think Zubrin's recognition of need (when he wrote *The Case for Mars*), does not go far enough.

Time The future is as close as today's next minute. "Today is the end of the world as we know it." The future is change. It is change that we create ourselves in our busy human world. It is change that happens in our universe, which we don't understand yet. In the past, both varieties of change have included very unwelcome elements. They will again. These two varieties of change relate only marginally, one to the other.

What will we become, all of us now on Terra? I'd like to feel our grandchildren and later descendants will see a much better world than exists today. It's possible in concept. However, I can't feel optimistic concerning what will develop here on Terra in reality. It gives me a sense we need an independent alternate branch. We need settlements and a business ecology in space, able to survive over long time separately from whatever happens on Terra. Will it happen? Soon enough? Time will tell.

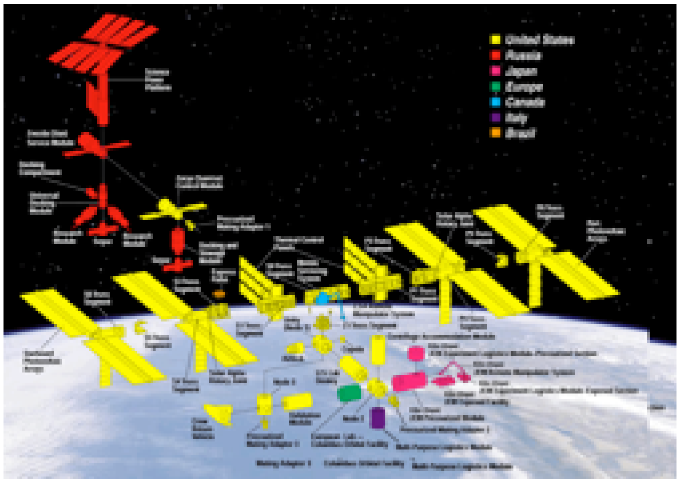
What will our universe bring to us, here on Terra? I'd like to see a peaceful universe that allows us humans to develop our potentials, with no interference from outside. That's a dream. We know today that about 96% of this universe we are in is different stuff from the baryonic matter that is ourselves. We know there are objects moving out there that could pass through our own Terra or through our Sol as if these were a thin gas. (There is reason to believe that on a tiny scale, something like this happened recently.) And that there are less exotic objects -- Near Earth Orbiting asteroids -- that might drop in from some unexpected direction, at several miles per second, to accomplish the same general effect locally as many megatons of TNT. Might this actually happen, someday? Yes: we can depend on it. When? Time will tell.

Finally, we can see the risk of religious ideologists and of opportunists of various kinds. A sort of fulminating ignorance, and worse, empowered by technology anyone can buy who has the money. These are people who imagine, for instance, that if our Terran culture were devastated, then it would magically reconstitute itself as a utopia. This would be an unwelcome experiment. What would come of it? I hope we never come to this, but if we do -- Time will tell.

The key element for these possibilities, and for all imaginable others, is *time*. We *do not know* how much time that is. Is it minutes from now? Then we're lost. Is it millennia? Nice, but unlikely. In any case, time is the wrong thing to be thinking about. The topic wants to be: *Off-Terra Settlements Now*. **<MDW>**

The International Space Station as a Working Model for an International Lunar Research Park: *Good Features & Deficiencies*

By Peter Kokh kokhmmm@aol.com



Above you see a color coded ISS "map" that shows which nations have contributed which components to ISS. For the original full-size image with legible script, go to:

http://www.geocities.com/utcnova3/components_large.jpg

To see this in timeline perspective in a computer-generated animation of the entire ISS assembly sequence (no audio), go to:

www.space-video.info/iss/assembly-animation.html

The story of ISS assembly is amazing. To destroy all this just 6 years after its completion in 2010, would, in our opinion, rank right up there with the burning of the great Library of Alexandria. The arguments that NASA gives for deorbiting this complex and flushing all that expenditure by many nations down the toilet, are quite irrelevant and beg to be refuted. If NASA gets its way, the public will be outraged and never again support a major public space initiative. That price will be much higher than whatever it takes to keep the station in orbit.

Yes, we can, and will build new stations out of less expensive inflatable modules such as those Bigelow Aerospace is testing. But those stations will serve other more commercial and industrial purposes. ISS as an international orbiting science laboratory is priceless.

An effort to declare the US portion of ISS to be a "National Lab" is a good start and should be supported. But if NASA as prime contractor and maintainer needs to be replaced, instead of throwing the baby out with the bathwater, we need to find or create an entity to take NASA's place. This entity could be multinational or international. In 2001, the Space Frontier Foundation floated the idea of an Authority to take over. Whether they had in mind an entity like the Port of New York/New Jersey Authority or not, I am not sure. But the idea begs study. We have six years to get an alternative up and running.

An International Orbital Research Park

The Moon Society is currently studying and developing the concept of an "International Lunar Research Park." If we replaced NASA in the ISS control regime with an Authority, most of what NASA has contributed, the framework, solar panels, some docking ports, etc. would fit in with what we see as a contractor provided and maintained infrastructure into which the individual national space agency facilities would plug, and be able to begin science, exploration, and research, just as they have in fact done at ISS. So instead of an "Authority" type entity, a willing multi-national corporate contractor could buy the NASA-owned infrastructure. A dream? Only if by being passive, we let it remain a dream.

What would motivate an multinational contractor to take on such an enterprise? Well, frankly, just that! Enterprise! The idea would be to support research partly by looking for profitable applications, and partly by expanding ISS to accommodate commercial operations. Such as? Such as a refueling depot, a waste processing facility, a visitors center. What could be done in this regard that did not interfere with the ongoing science research programs, is probably a lot more than any of us imagine, myself included. Here, we might look at another idea floated by the Space Frontier Foundation, even earlier, back in 1992: AlphaTown.

I have put both SFF proposals, in the abridged form in which they appeared in MMM's #92 and 139, online for your review, at this address:

http://www.moonsociety.org/publications/papers/AlphaTownSSAuthorityProps2.pdf

ISS - ILRP similarities and differences

Like ISS, an International Lunar Research Park would be built component by component, phase by phase. It would begin to be operational once the first national space agency science outpost was plugged into the growing contractor-provided infrastructure. Like ISS, the ILRP would grow in structure and functional capacity but in a more open-ended way.

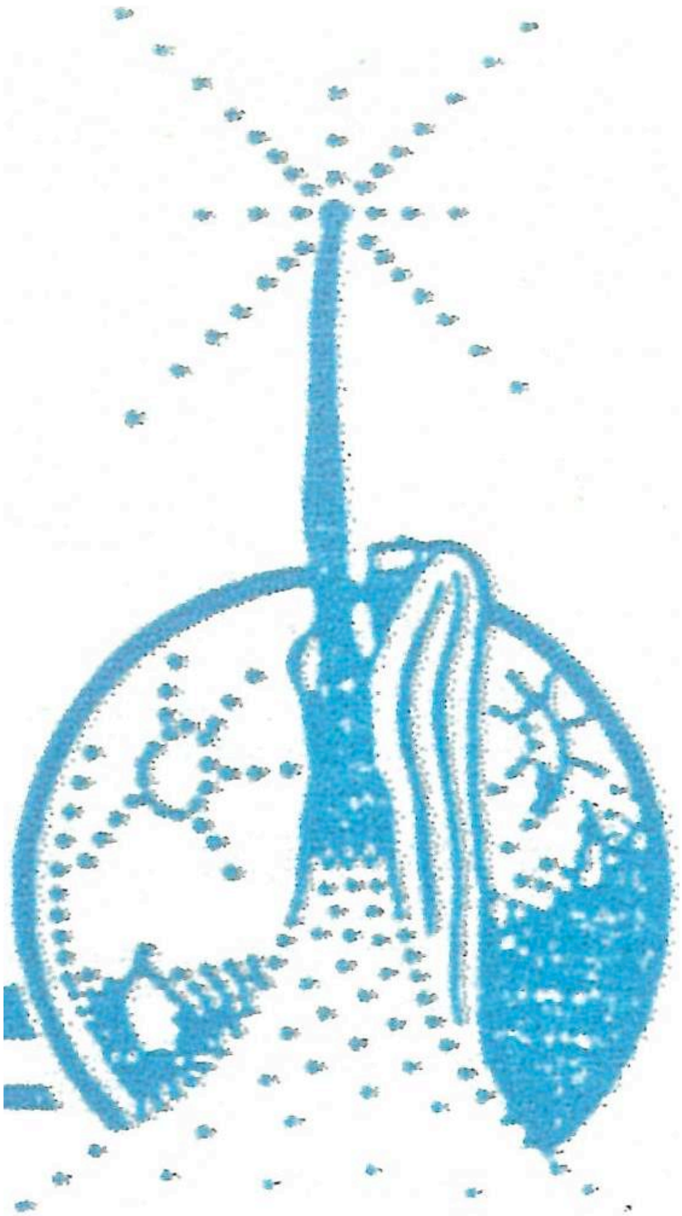
ISS growth could be limited by the capacity to keep reboosting it to its preferred operational orbit. Unlike :Low Earth Orbits, locations on the Moon's surface do not decay, however, if the original site is as limited by typography and lighting as the Washington DC "Mall-sized" area available on the South Pole Shakleton Rim, then growth will stall, or need to be halted, long before operational and functional options have been exhausted.

ISS Growth Vectors: where are we now?

The COTs program, which is intended to incentivize the development of commercial space transportation vehicles to bring cargo and personnel to ISS after NASA's Space Shuttle Fleet is retired, is a step in the right direction, i.e. in the direction of commercialization. There are those who want to postpone the fleet retirement. Their motives are admirable, but in our belief, this would be a big mistake. Europe, Russia, and Japan are building new ISS-access capable vehicles for cargo and/or crew alike. An extension of the fleet retirement deadline would be a disincentive to continue these developments.

Replacing the Shuttle Fleet is the first step. Replacing NASA as owner/operator/landlord with a multi-national contractor is next. Admittedly, this will be a very controversial step. But contrary to common opinion, NASA, as a national "socialized" space program, is simply not "as American as Apple Pie." It is a deviation from the American way that has gathered much support, boding ill for the American "way of life" in general.

Replacing NASA as landlord could open participation in ISS to more international partners. In our opinion, freeing NASA from ISS duties, would be good for the agency, allowing it to move on to pursuing the exploration and research & development. **<PK>**



The Logo of **Lady Base One** Corporation (1987-89)

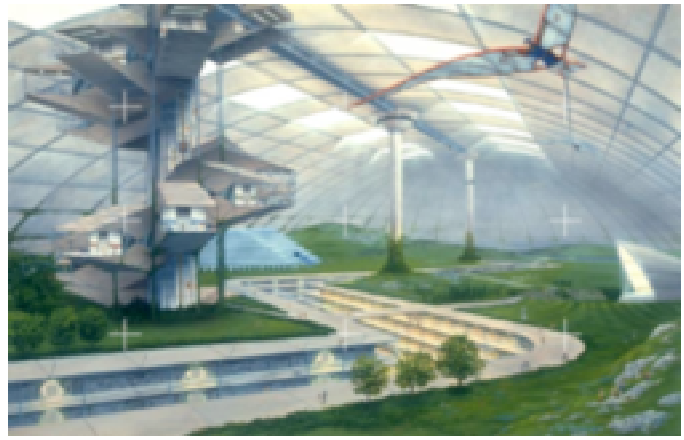
Mother Earth reaching for the stars using the Moon as a stepping-stone.

Lady Base One™ was an early effort to erect not just a commercial Moonbase, but a private enterprise industrial "settlement". This project preceded Gregory Bennett's **Artemis Project**™ by some seven years, and with a multi-millionaire as its leader, looked promising for a while. But William F. Mitchell's fortune was made in the Houston real estate market, which collapsed in the recession at the start of the first Bush presidency in '89.

But we are interested here, in the symbolism of the logo, not in what led up to the collapse of a bright dream, that had many of us at the time, very enthused. Mitchell's initiative served to awaken a determination in many of us to see something happen within our lifetimes.

The Myth that Space Settlements are a creation of Human Hybris

Almost everyone thinks of any and all proposals to establish an outpost or any more extensive human presence on the Moon, as just that, "a human effort." Indeed, if we are looking at NASA or other agency designs through the years, or even if we are looking at various science-fiction visions of lunar settlement, with the exceptions of the 1970's classic film "Silent Running" and the 1990 made-for-TV ABC film "Plymouth," what we see and read about are principally more or less elaborate constructions for humans and a few token houseplants.



This depiction of **Moonbase Main Plaza** by Pat Rawlings got more exposure on the cover of Ben Bova's 1989 book "Welcome to Moonbase." But it had debuted previously on the Lady Base One™ poster.

Biosphere I is Pregnant

But in the vision we have outlined in two "Eden on Luna" theme volumes*, a different picture emerges. It would seem that humans can establish themselves securely on the Moon, only if they in turn are "hosted" by reestablished ecosystems in biospherules "budding off" of the home planet Biosphere, "Biosphere 1" itself.

[* www.moonsociety.org/publications/mmm_themes/]

In this light, we are not leaving Mother Earth for a barren world, but establishing an exclave of Mother Earth herself, Gaia, if you will, on a world that will, in the process, manifest a hitherto unsuspected "fertility," a fertility hidden all these past 4.5 billion years, by the absence of a fertilizing agent.

We have finally reached the point in the development of Earth-Life, now spearheaded by an emergent species capable of exercising stewardship, and alone capable of bursting through the boundaries of the atmosphere to replant "gaiacule sprouts" elsewhere throughout the Solar System, and someday beyond.

Humanity is not a biosphere cancer

Some look on humanity as a cancer on nature. But in many species, the coming of reproductive capacity brings with it a severe strain on the rest of the system. In fact, in many species, such as the Octopus, the female dies after laying eggs, its work done.

Think about it this way. Earth life cannot possibly sprout beyond the atmosphere except via the emergence of a technologically capable species. That process, especially as that species' technology develops, is bound to be at a cost, imposing stress on many other species populations sharing the globe, and with it, a considerable amount of extinctions. It is a price that, under the most idyllic of imagined alternative situations, would have to be paid. But think of the reward!

In the process, the dominant technological species, must come to grips with its own injurious effects on the

Biosphere, and gradually learn to minimize "co-lateral damage" and to evolve from "blind domination" to "enlightened stewardship." That is the direction in which we are moving now, although not yet without a lot of "kicking and screaming" holdouts who have not yet gotten with "the program," and who are more interested in avoiding personal inconvenience, even at a clearly indicated cost to their own children and grandchildren.

Some people are uncomfortable thinking of humanity as the "reproductive organ" of Nature. I don't understand why. Sexual reproduction is a wonderful thing and has been around for billions of years, and without it all the visible plants and animals we are familiar with, including ourselves, would not exist.

Human space transportation as a door-opener

But if you cannot emotionally wrap yourself around that idea, try this alternative concept: Humanity is a nature-emergent force that has been able to pierce the atmospheric boundary that has confined Gaia to the Earth-space below, and open up hitherto barren worlds beyond. In this paradigm as well, humanity is the first species capable of bursting this bond, and of taking representative eco-systems along, for transplantation and husbanding off planet on new planetary shores.

System-Faring 1 graduates to System-faring 2

Mitchell's point is that Mother Earth is the ultimate agent behind "our" (Gaia and Humans together) breakout into the larger host System. Humans have been a "system-faring species" for a hundred thousand years, the system being one of the continents that share Biosphere 1. Now we are capable, at last, of bursting into the next System Tier: the Solar System.

The Moon is just the first of many destinations. Mars will quickly follow, and prove, no doubt, even more fertile ground. These seemingly bold steps are really akin to Africans first making it through the Sinai and across the Straight of Aden to establish the first early beach-heads in Eurasia. So, as bold as the idea of full-fledged lunar and Martian Settlements may seem, it is bound to be seen, in retrospect, as just the humble beginning. It took us tens of thousands of years to get from Aden and Palestine to where we are now: virtually everywhere on the seven Continents, and moving with ease back and forth within mere hours throughout this First System.

It will be a long time before humans effectively occupy the entire Solar System, when travel between the various "Earth-life colonies" will be as casual and matter-of-fact as it is now between continents. Undoubtedly, establishment of the first true lunar settlement will be a matter of great pride and achievement, an achievement undoubtedly hard won. But it will only be the beginning.

In time our presence, humans hosted by Gaian eco-systems, will span the lunar and Martian globes. In time there will be human-Gaian outposts among the asteroids, on the moons of Jupiter, Saturn, Uranus, and Neptune: and, yes, beyond.

It took us a hundred thousand years from our fist humble steps "out of Africa" to the point we are now as an intercontinental system-faring species. At last we are ready to upgrade to the larger Solar System above and beyond. It may take us well more than a century to develop the means needed to establish ourselves throughout the Solar family and to become as truly "system-faring" out there as we are now down here.

Someday, System-faring 3: *Ad Astra! To the Stars!*

Nor will that be the end, as beyond lays the endless system of interstellar space. This writer is a firm believer that the speed of light is an absolute barrier and that all the talk of time-travel and wormholes and hyper-space is so much theoretical nonsense.

If you mean by "travel" an ability to make *round trips within one's lifetime,* then, for me at least, we will never see "interstellar travel." If we perfect "suspended animation", we may be able to make round trips, in a sense, but still not really, because we will return to a world considerably different from the one we left, to a world that has moved on - our grandchildren's world.

Interstellar "migration" is another thing. This *will* happen, and over millennia and longer, humans bringing Gaian ecosystems with them, will spread slowly through-out the nearer interstellar reaches and beyond. In time, we will have spread so far that mutual contact will become patchy. Old Earth will have become a treasured, even sacred myth with the historical details becoming more a matter of belief. Languages will have evolved differently in different locations. The ability to read the ancient scripts may not be maintained.

The point is that humans will not go alone. We are a Gaian species, inseparable from Gaian ecosystems. We will make the journey together.

What does this say about interstellar ships - or should we be thinking of "arks" and/or "generation ships?" Won't they need to be large enough to support viable eco-systems? That is another question. We may launch interstellar ships with everyone and everything in deep metabolic sleep, to be slowly awakened only upon finding a suitable new setting. We can only guess.

So do not think of humans, of whatever nation-ality, as establishing a viable lunar settlement. Think instead of the first lunar settlement as the first trans-atmospheric offspring of Mother Earth herself.

And, of course, sometimes a valiant first effort fails. We will try again, even if some time goes by.

Earth and Gaia as Host and Symbiote:
Budding new symbiotes for new host worlds

We can also think of Gaia, Earthlife, as a native-emergent symbiote of its geological host, Earth, a body of rock, water, and atmosphere. Of course, in that symbiosis, Earth itself has been transformed, even if superficially. But now Gaia has matured, having budded a dominant species capable of transporting seedling "gaiacules" and implanting them in other geological host bodies: the Moon, Mars, other bodies in the solar system.

Mother Earth is not a spinster
Mother Earth and Father Sky are inseparable
Attitude is everything!

To all my fellow dedicated environmentalists, we must stop thinking of Mother Earth as a spinster. We must start thinking of Mother Earth and Father Sky as a holistic pair, a pair "made in heaven." In such a vision, there is real room for environmental enthusiasts and for space enthusiasts to come together fruitfully and productively in a common shared greater and more holistic vision, an inspiration that can take us forward together into a future in which a healed and healthier Biosphere I will be surrounded by an ever growing family of healthy human-stewarded mini-biosphere offspring.

How could the future be brighter? **MMM**

Resources of Mare Imbrium and Oceanus Procellarum

By David Dietzler 2009

The Ocean of Storms and Sea of Rains offer interesting possibilities for resource utilization on the Moon. These resources might be of great value to lunar and Earth orbital industry as well as Mars colonization in the future.

1) KREEP terrain:

[Potassium (K), Rare Earth Elements, and Phosphorus (P)]

Some of the richest KREEP terrain exists around the rim of the Sea of Rains (Mare Imbrium) and in the Ocean of Storms (Oceanus Procellarum). This could be a source of potassium and phosphorus, the two major fertilizer ingredients with nitrogen being the third, needed for agriculture. Potassium hydroxide could serve as a caustic for chemical processes. Phosphorus is indispensable for making solar panels. While p-type solar panel material might be made by doping silicon with aluminum instead of boron (which is rare on the Moon), n-type material must be doped with phosphorus.

We won't get very far on the Moon without electricity and we can't get solar panels without phosphorus so it seems reasonable that industrial bases should be located near KREEP terrain. However, it might be argued that solar thermal electric generation systems with aluminum or magnesium reflectors and titanium or steel boiler tubes and turbogenerators could be made anywhere on the Moon where Ca and Al rich highland regolith and Fe-Mg-Ti rich mare regolith are available such as a (mare/highland) coastal location. Solar thermal electric systems reach 25% efficiency while silicon PVs are 10-15% efficient. Solar thermal systems are more complex therefore they require more maintenance. Presently it is not known whether silicon PVs or solar thermal systems offer more practicality and economy when it comes to making them on the Moon. Lunar manufacturing is still in its infancy. Hard data will be required to make this decision.

KREEP also contains rare earth elements. These REEs might be used for alloying iron, steel, aluminum, magnesium and titanium since many of the elements commonly used for alloying on Earth are lacking on the Moon. REEs are also used in many electronics applications and as catalysts. Their industrial uses are too many to be listed here. For more information, see:

http://www.rareelementresources.com/s/Uses.asp

Thorium and uranium are also found in KREEP. These elements might be used as nuclear fuels for space ships built of lunar materials in the future. Thorium itself is not fissile, but it can be converted to U233 in a breeder reactor primed with U235 and eventually plutonium. While thorium and uranium are only present at parts per million, proposals have been made for extracting uranium from granite on Earth that contains only 4 ppm U and seawater where uranium is present only in parts per billion. So the extraction of thorium and uranium from KREEP is not totally unrealistic.

2) Pyroclastic glass.

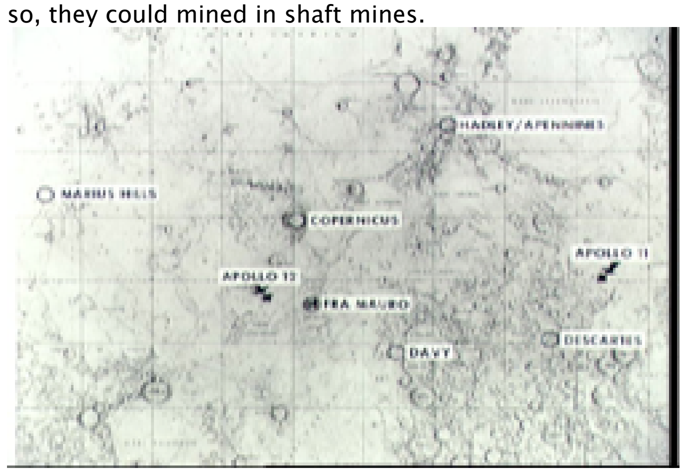
Volcanic glass, also called pyroclastic glass, is found in many places on the Moon. The largest deposit is in the Ocean of Storms just west of the Aristarchus Plateau (area 37,400 km^2.) Glass from volcanic fire fountains contains more chlorine, nickel, copper, zinc and gallium than is common in regolith and these elements can be obtained by roasting the glass particles [1]. The glass can also be reduced with hot hydrogen to gain oxygen.

The Aristarchus Plateau as seen from the NW Deep, bright Aristrachus at left, Herodotus at right, Schroeter Valley winding below

Chlorine is needed to extract aluminum by electrolysis, make silane and silicones, form silicon tetrachloride to obtain pure silicon for PVs, and table salt when combined with lunar sodium. Nickel is useful for iron and steel alloying and as a catalyst for shifting hydrogen and carbon monoxide to methane and water. Copper and zinc are used for alloying aluminum and magnesium respectively. Gallium can be combined with arsenic to make high efficiency solar panels.

3) Volcanic gas?

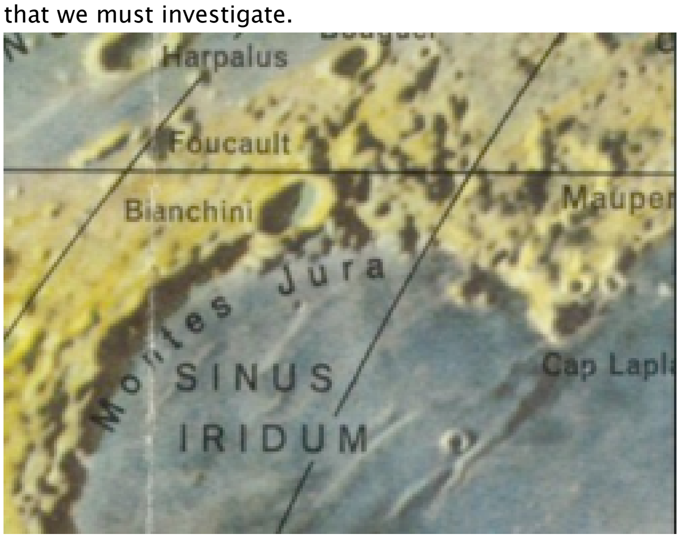
This one is highly speculative. The Marius Hills in the Ocean of Storms contain over 200 low volcanic domes. Could there be intact chambers of volcanic gas there? Could this gas contain carbon monoxide, sulfur compounds, even water? Subduction zone volcanoes on Earth, like the famed Mt. St. Helens, emit lots of water vapor from the ocean drawn under by geological processes. Hot spot volcanoes like Hawaii also emit water vapor from deep within the Earth though not as much as subduction zone volcanoes. The domes of Marius Hills will be more like hot spot volcanoes. Some of the same elements found on pyroclastic glass particles like chlorine and copper might be concentrated below these domes. If so, they could mined in shaft mines.



We will need lunar orbiters with powerful ground penetrating radars to investigate below the surface of the Moon. We will also need landers with geophones, sort of like underground sonar systems used to hunt for oil on Earth, and explosives or inert projectiles collided with the Moon to set up vibrations in the Moon that might reflect off of sub-selene formations including volcanic gas pockets. Then we will need robotic landers with drills to tap this gas, should it exist, and analyze its composition.

If we found large quantities of CO, S compounds, even H_2O beneath the Moon, this might be easier to tap by drilling than mining for ice in near absolute zero cold trap craters in polar areas. Carbon monoxide gas could be combined with lunar oxygen obtained by molten silicate electrolysis perhaps to make CO_2 for CELSS. It could also be used for carbon for steel making, other metal extraction processes, even metal matrix composites like graphite/magnesium or silicon carbide/aluminum. Hydrogen from water could be combined with carbon to make some plastics. Sulfur could be used for sulfur concrete and sulfuric acid for metal extraction.

There is also the possibility that the Moon is "burping" radon from its interior. While radon is not very useful, its presence, should it exist, indicates the decay of uranium. Could the domes of Marius Hills exist because of large quantities of uranium below the surface decayed and released heat? Could there be more uranium and perhaps thorium too down below in richer deposits than KREEP which only contains about 4ppm U and 10 ppm Th? Since uranium decays to lead, could there be lead down there? Lead might not be useful as an industrial metal but it can be used to stain glass and get real red colored glass thus it would be valued by lunar artisans. Further, lead could also be used as a dopant superior to Sodium and/or Potassium to lower the melting point of mare regolith for use as a matrix in glass-glass composites. Perhaps shaft mines could be dug with cabled teleoperated robots to get at these speculative deposits of uranium, thorium and lead. While these sub-selene resources of volcanic gas, other elements and radioactives are mere conjecture at this time, the possibility of their existence is so tantalizing that we must investigate.

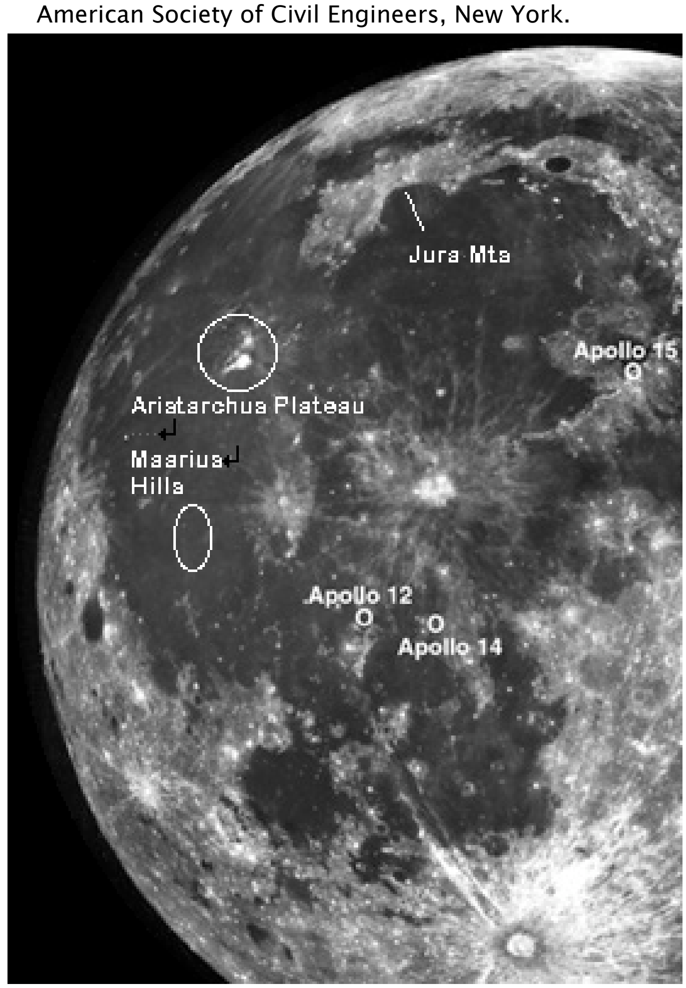


Location of a mining base or mining bases within the range of ground vehicles for access to the KREEP terrain, pyroclastic glass deposits and volcanic domes of Oceanus Procellarum will require more study. I don't have the required tools to measure distances on the Moon, but by simply eyeballing a map it looks like Aristarchus and Marius are much closer to the KREEP terrain of Mare Imbrium on the coast of the Jura Mountains that form the NW ramparts of Sinus Iridium (Bay of Rainbows) than to the KREEP terrain of Procellarum to the east near the Sea of Clouds (Mare Nubium). The base or bases should be located near a coast so that Fe-Mg-Ti rich mare regolith as well as Al-Ca rich highland regolith can be mined.

Off road vehicle convoys and railroads will be needed; perhaps pipelines too. The base, or bases, would initially consist of an "industrial seed" of robotic mining, regolith refining and manufacturing devices that could self-replicate using only lunar resources and small cargoes from Earth. Small human crews would supervise the robots. As the seed grows into full-fledged smelters, factories and larger habitats, more humans will go to the Moon. Industrial production will have to reach a scale at which millions of tons of materials were produced every year for a solar power satellite-building project.

Thousands of large helium 3 mining tractors would be built also. Scientific research, tourism, Moon made ships for asteroid mining and asteroid deflection forces to repel asteroids on collision course with Earth or our bases on the Moon, support for Mars colonization efforts in the form of metal for spaceships and propellant as well as equipment to be used on Mars mined and made on the Moon, and probably unforseen uses of lunar materials, will all emerge.

1] Cooper, B.L. (1994) Reservoir estimates for the Sulpicius Gallus region. Space 94: Engineering, Construction and Operations in Space, pp. 889-896. American Society of Civil Engineers, New York.



Industrialization of the Moon

Defining the Lunar Industrial Seed: What Comes Before How?

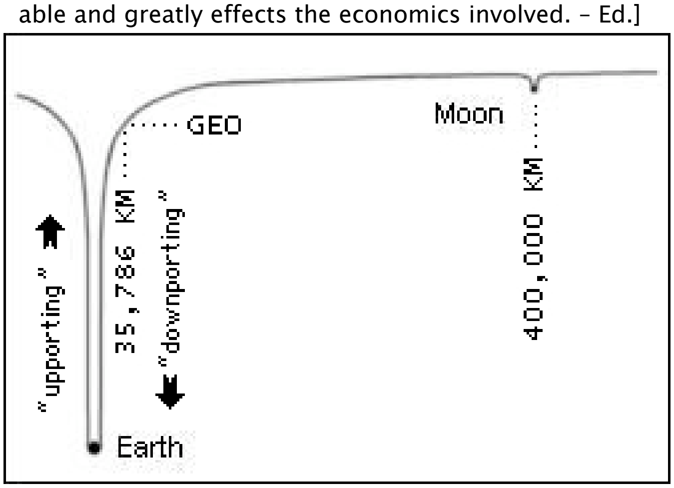
By David Dietzler pioneer137@yahoo.com © 2009

Part 1) What We Need

Seed Products and Mass Production

Given the high cost of space transportation it is necessary to minimize upported* mass to save money and make a solar power satellite project economically feasible. The mass of the lunar industrial seed must be kept as low as is possible while still making it possible for the seed to mine, produce materials, self replicate and manufacture everything from bricks to mass drivers on the Moon. Before we can determine the components of the seed we must ask, "What are we going to make?" Before we answer the question, "How are we going to make it?" we must design before we manufacture and we must design for manufacturing. In other words, we must design things that can be made simply and economically with limited lunar materials.

[* One frequently hears that there is no “up” or “down” in space. That is a half truth, as space is sculpted by gravity which affects the motion of everything. Earth, being 80 times as massive as the Moon, has a much deeper “gravity well,” and it is proper to speak of ‘upporting’ items from Earth to the Moon, and ‘down-porting’ things from the Moon, to GEO, LEO, or to Earth itself. The difference in fuel costs is consider-able and greatly effects the economics involved. – Ed.]



At first we will upport complete inflatable habitat modules with electrical and communications systems, life support systems and interior furnishings. We will also upport vehicles, mining machines and robots. Once we get a small base established we will start making things by the use of human/robot synergy.

If we are to grow a lunar industrial seed massing from several hundred to several thousand tons into lunar industrial complexes amassing millions of tons we will have to engage in mass production. Standardization is one of the keys to mass production. We need to figure out, or somebody else does, how to make in no special order standardized lunar products such as:

LOW TECH ITEMS

- a brick (interlocking?)–cast basalt, glass and ceramic from magma electrolysis
- a block–same materials as above and possibly from concrete also
- a slab–ditto
- various tiles–ditto
- a sewer pipe–ditto–this could also be used for air ducts
- a water pipe–ditto, and metal pipes too
- elbows and Ts for both pipes–ditto*
- water faucets, plumbing parts like shower heads, etc.*
- a steel or pure iron rail
- a tie, unless we go with monorails _various steel, pure iron and titanium bolts, rolled threads*
- various nuts*
- various iron plates
- an iron beam
- an iron stud
- a cement board and maybe a drywall section**
- various gauges of aluminum wire with glass cloth insulation
- various electrical parts–a switch, connectors, junction box, etc.*
- a door frame that can have either glass or metal plate in it
- a door knob*
- a hinge*
- a non-insulated water and sewage tank
- metal pipes for conveying high pressure gases
- a toilet***
- a bath tub or shower stall
- a planting box–made of bricks or blocks i guess
- a sink
- various pieces of furniture made of CB, metal or AAC
- a glass fiber cloth sand bag for piling up regolith sand bags around modules for rad and therm protection. this bag could also be used for cement and groceries, etc
- a bottle* that can also be filled with various beverages
- a half gallon milk bottle*
- a canning jar that can double as a foodstuffs jar*

* **[bottle, jar]** These items will be small, lightweight, and not needed in very large numbers during the early base construction stage lasting perhaps six months to a few years, so they will be upported until lunar manufacturing capacity grows and these parts are needed in large numbers and high total masses. While some might say, "What? a water faucet when it costs thousands of dollars per pound to the Moon?" I can only say that the machines and manpower needed to make these in the early stages when there is low demand for these might far outweigh the items themselves; and since time is money we need to get a base built and expand it rapidly. Upported bottles could be made of lightweight plastics and even plumbing parts too. When we get metals and glass on the Moon, old thermoplastic parts could be ground up, melted down and turned into more valuable products.

** **Cement board** is preferred to drywall. Cement can be made simply by roasting and steaming highland regolith; while making drywall will require sulfuric acid leaching. Drywall is more fragile than cement board; and it can be made by laying plaster between two sheets of glass fiber cloth, so facing paper is not needed. It’s easier to saw, but that produces lots of dust. We might be leaching regolith is sulfuric acid during aluminum extraction and this will lead to lots of calcium sulfate, which is plaster, and silica for glass. There are aluminum extraction processes that don't require acid leaching but it's too soon to tell what process will be used. If we do acid leaching that plaster by-product should be put to use. If not drywall, then for aluminum and magnesium casting molds and medical casts.

***Flush mechanisms would be upported for toilets. If anything has to work right, this does (lol).

MORE COMPLEX ITEMS

- a silicon solar panel
- an airlock and hatches etc._various electric motors-these might be among the more complex lunar manu-facturing jobs we must do. Mark R. has pointed out that large motors will need cooling systems
- a high pressure gas storage tank
- an insulated cryo liquid storage tank_valves for hp gas pipes
- a heliostat
- a fiber optic bundle
- an electric stove
- a refrigerator
- a ventilation fan
- a cooling unit _compressors? _space radiators?
- a solar furnace, therefore a reflector system
- Vehicles-two-a van and a truck made by stretching the van and sticking 4 std wheels on the back end with std electromagnetic brakes and std motors in each wheel. Std batteries wired in paralell. see:

http://www.moonminer.com/Lunar_Model_T.html

Heavy equipment:

- one volatiles harvestor model
- one mining shovel model
- one small crane model and
- one large crane model that can also become a drag line

Standard vehicle and heavy equipment parts, frames, etc. will be necessary. This will get complicated. We will have to keep designs as simple as possible and leave out frills.

Machine tools: drill presses, lathes, milling machines, CNC machines, perhaps something like the Multi-Machine will be central to machining products on the Moon. see:

http://groups.yahoo.com/group/multimachine

Mass drivers: these will be the crowning achievement of lunar industry, allowing the export of lunar materials into space for construction of powersats, telecomm platforms, colony ships to Mars, robotic asteroid mining ships, etc. Many of these items will be very complex and require an advanced manufacturing capacity on the Moon.

We will follow Peter Kokh's MUS/cle strategy [www.lunar-reclamation.org/papers/muscle_paper.htm] and make the Massive, Unitarian and Simple parts like refrigerator casings on the Moon and upport the guts of the machine-coils, compressor and motor [1]. The complex, lightweight and electronic (or expensive) parts of compressors, cooling units, fans, valves, etc. will be upported and the MUS stuff like iron casings will be Moon made. Machine tools will be very complex and demand exacting tolerances. At first, during the early years of base development, we will upport them. We will have to upport 3D additive printing machines like Direct Metal Laser Sintering devices to make the finer parts and we will upport the finer parts like the precision motors of lathes until we get the ability to make them on the Moon, while heavy metal bases and frames could be Moon made. We will also upport lots of solar panels of the highest efficiency and lowest specific mass available because nothing will work without power and expansion without power will be impossible.

The list above is certainly incomplete. I welcome others to modify and add on to the list.

Works Cited Part 1

MUS/cle Strategy for Lunar Industrial Diversification
© 1988 The Lunar Reclamation Society
www.lunar-reclamation.org/papers/muscle_paper.htm

Note, this paper in its entirety is online at:

http://groups.google.com/group/international-lunar-resarch-park/web/lunar-industrial-seed?hl=en

Yet to come (future installments):

Part 2: Lunar Materials

Solar Wind Implanted Volatiles-Those Precious Light Elements
That Essential Oxygen
Cast and Sintered Basalt
Silicon and Iron
Titanium and Titanium Dioxide
Magnesium
Aluminum
Cement
Glass
Sulfur

Part 3A: Manufacturing – "MUS"

Furnaces
Liquid Gas Storage
Solar Panels Needed Early
Basic Bricks
Metal Plates
Contour Crafting
Extrusions

Part #3B: Manufacturing – "cle"

3D Additive Manufacturing
Chemical Vapor Deposition
Spinning Metals
Blacksmithing
Nuts and Bolts
Electrical Parts
Glass Working
Sand Mold Casting
Robots and Electric Motors

Part 4: Conclusion

Timeline

Dave Dietzler of the Moon Society St. Louis chapter, has been contributing quality technical articles in MMM since #158, August 2002. Besides his many articles, his input has improved many pieces written by the editor. Dave is also a member of the Moon Society Board of Advisors.

20 Questions about Resources from the Moon

Q. What is the Moon made of?

A. Tests on Apollo Moon rock samples showed that they contain high percentages of Oxygen, Silicon, Iron, Aluminum, Titanium, Magnesium, and Calcium with lesser amounts of many other elements

Q. Are not these elements common enough of Earth?

A. Yes, these same principal eight elements are the major constituents of Earth's own crust.

Q. Then what is the advantage of extracting such commonplace resources from the Moon?

A. There is no advantage at all if the idea is to bring them to Earth itself. But because of the Moon's much lower gravity, 1/6th that of Earth's, it would take only 1/20th the fuel or energy cost to transport these raw materials all the way back to Low Earth Orbit (LEO) or to Geosynchronous Earth Orbit (GEO) rather than rocket them up the short distance from Earth's surface. In LEO and GEO, we could then afford to use building products made from these raw materials to do a lot of interesting things.

Q. What sort of useful building products could be made from these few elements?

A. Eventually, we should be able to make high-quality metal alloys such as steel (from iron), aluminum, titanium, and magnesium – the four "engineering metals." But this would require an elaborate industrial complex. In the short run, it would be relatively easy to make serviceable sintered iron products, glass, fiberglass, and a glass-glass composite on the analogy of fiberglass-reinforced plastics. We can also make some ceramics and even concrete (on Earth, the #1 building material by far.)

Q. What things in particular would these cheaper lunar resources allow us to build in space?

A. Much larger "space stations" than we can now afford to haul up from Earth module by module is one example. And only with these "cheaper" raw materials could we ever afford to build orbiting factories to take advantage of vacuum and micro-gravity to make things that can't be made on Earth's surface, or orbiting hotels and resort complexes for tourists to enjoy spectacular views of Mother Earth, or the large orbiting Solar Power Satellites to provide Earth with inexhaustible clean power.

Q. Given Earth's two most pressing problems, our deteriorating environment and poverty in developing nations, how can we justify the high up-front costs of tapping lunar resources?

A. Many things are contributing to our deteriorating environment, but easily the number one villain is electrical power generation from coal and oil burning plants that fill the air with acid rain and greenhouse gases that will eventually destroy the climate. Even if the more developed nations would switch to all nuclear power generation, an option with its own unwanted consequences, people in the developing nations would have no way to catch up in standard of living except by burning even more fossil fuels tha we do today, specifically coal. Space-based power generation is ultra-clean and there is no end to the amount available where the Sun provides it free full-time. Without such spade-based electrical power generation, Earth's environment and the World's developing populations will share the same death sentence.

Q. Besides the more abundant elements mentioned, does the Moon have truly strategic resources?

A. A big surprise was that the Apollo Moon Rocks contained 600 times as much of a rare form of helium, helium-3, as is found on Earth. This endowment is not native to the Moon and is only to be found in the upper meter or so of the ubiquitous rock powder blanket (regolith). It was apparently put there by eons of buffeting of the Moon by the wind or particles streaming out from the Sun's hot atmosphere, the "Solar Wind." If we ever succeed in engineering workable fusion power plant, Helium-3 would be the ideal fuel as burning it produces no radio-active particles, not even neutrons, only charged particles that can produce electricity directly. There is enough of this "ultimate fuel" in the Moon's dust blanket to provide Earth with all the power we want for thousands of years.

Q. What chance is there of unhappy side effects of generating our electrical power in space?

A. Power from orbiting Solar Power Satellites will have to be beamed down to Earth either by laser or by radio waves in the microwave range – *but not the same as those in your oven, which would be dissipated by water vapor in the atmosphere!* Tests to date deliberately using insect and bird species that might be most vulnerable to such waves have encouragingly shown no ill effects. There are fail-safe ways of controlling the beam and keeping it on target to ground-receiving stations (rectennas.) But some economic dislocation of coal miners and petroleum workers is the unavoidable price we'll have to pay for either a Solar power Satellite Network or a Helium-3 fusion plant system Yet putting these systems in place could employ even more people than those put out of work, especially in developing countries. A clean Earth and a decent standard of living for all are the reward.

Q. Where on the Moon is this wealth to be found, and just how would we go about extracting it?

A. On the Earth, long and powerful geological processes in the presence of water have worked to concentrate much of the mineral wealth in scattered veins and lodes of ore. On the Moon this did not happen and these minerals lie everywhere in similar concentrations. The dark maria or Seas are richer in iron and titanium, the light highlands richer in aluminum, magnesium, and calcium. There need be no race to "stake out claims." Eons of meteorite bombardment have pulverized and "gardened" the Moon's surface into a powdery blanket 2-10 meters deep. All we need is here, and much of the "mining work" has already been done for us.

Q. Won't mining operations scar the Moon with open pits and unsightly piles of unwanted tailings?

A. As we've just seen, the mineral wealth of the Moon is lying loose on the surface. In essence, we just need to rake the top meter or so of the moondust to harvest what we need. We will want to do this in generally flat areas, going around big craters, etc. So there will be neither deep mines nor open pits, and the minerals not needed will be left in place. A visitor would have to come very close to tell that anything had been done. There will be no insulting eyesores. From Earth, even with the most powerful telescopes, there should be no visible clues.

Q. How large a crew would be needed on the Moon?

A. Simple resource recovery operations could begin with perhaps a dozen people using tele-operated equipment where feasible. Liquid oxygen to use for air, and to combine with hydrogen to make water, and for rocket fuel would be the first product. With a few more people we could begin making things from cast basalt, and sintered iron; concrete objects and glass-glass composite products would be next.

Q. How could people live in such a barren place?

A. The first shelters will be compact space station type habitat modules and inflatable structures brought from Earth, covered with 2-4 meters of moon dust for protection from cosmic rays, solar flares, micrometeorites, and thermal extremes. Essentially this dust blanket will do for Lunan pioneers what our atmosphere blanket does for us. But fairly soon, crews should be able to move into much more spacious structures built from raw materials on hand. These roomy quarters could be flooded with piped-in sunlight and filled with plants to keep the air clean and fresh as well as providing fresh fruit and vegetables.

Q. Would miners sign up for short tours of duty? Or go on to stay and bring their families along?

A. Certainly, the first volunteers will only stay a few months at a time. But as the outpost grows, a point will be reached where it is cheaper to provide the facilities a permanent population will need rather than to keep shuttling personnel back and forth from Earth. As soon as possible, it will be helpful for some crew to volunteer as trial settlers, even raising some children. For until we can see how native-born children grow up, we cannot be absolutely sure that genuine settlement an long be maintained. To find that out, we need to take the plunge.

Q. What long-term consequences will there be for permanent pioneers and their children?

A. We can expect some loss of muscle tone and mass in adjusting to a lower gravity, but this loss should level off at an acceptable, healthy plateau. The longer we put off allowing volunteers to stay long-term, the longer we will have to wait to find out if this expectation is correct.

Q. Wouldn't a settlement of any real size need a continuous infusion of very costly imports?

A. The Moon has very stingy amounts of hydrogen to make water by combining with abundant local oxygen, and stingy amounts of carbon and nitrogen, all essential for growing food and fiber. These elements are present in the loose dust blanket, again as a gift of the Solar Wind, and we can harvest them by heating the dust to about 600 °C. If we do this religiously whenever we handle moondust as in road construction, site preparation, and mining and manufacturing methods, and recycle, again religiously, we should manage. The alternative is to import these elements at great expense. Eventually, richer sources of these "volatile elements" can be mined on nearby asteroids, even from the two small moons of Mars.

Q. To build a healthy, diversified economy, what else could the colony export besides building materials, rocket fuel, and fusion fuel?

A. Almost everything the pioneers would make for themselves to avoid unnecessary imports, will also find a ready export market in space-based installations in Earth orbit and elsewhere, "killing two birds with one stone."

Q. Even if all this development does not scar the Moon, won't it cause pollution there?

A. The settlement will need to operate as closed biosphere, recycling its air, water, and biomass. As settlers will have to live "downstream and downwind of themselves," they will have to keep their little oases of life fresh and clean. The host Moon itself has no atmosphere, groundwater or ecology of its own to pollute.

Q. What about the suggestion that the Moon might be used as a dump for Earth's problem wastes?

A. Even if waste disposal authorities on Earth become desperate enough to pay the high freight charges to send some problem wastes into space, it will be cheaper to let the Solar Wind slowly blow them out of the Solar System altogether than to land them on the Moon. If however in the toally safe, sterile vacuum and biological isolation of the Moon, it proves possible to "mine" such wastes for elements rare on the Moon, the settlers may welcome them.

Q. How far off in the future is all of this and how much scarce money will we have to invest?

A. The first genuine Moonbase is still on the drawing boards. Genuine settlement will require technologies NASA is neglecting such as closed biospheres and manufacturing under lunar conditions. It will be essential to get private enterprise involved. A lunar settlement could eventually become a very profitable undertaking, especially considering the limitless potential for electrical power sales. The up-front costs, admittedly high can be borne by utility energy consortiums rather than by public taxes.

Q. How inevitable is such an Earth-Moon economy?

A. Before private enterprise can get involved, the "infrastructure" to get us "back to the Moon to stay" must be in place whether through government or corporate funding. Tax monies "invested in the future" rather than "spent on present itches" may be needed. Earth-bound enterprises must be enticed to pre-develop technologies needed later, on the Moon and in space, for any profitable terrestrial applications that can be identified, now. This is called "spin-up" the very reverse of the much-heralded "spin-off" process about which most taxpayers could care less. Spin-up addresses the "What's in it for me?" question.

We can do it! ***###***

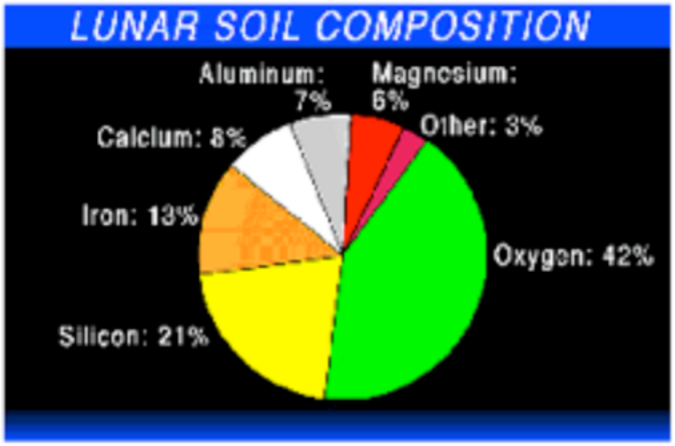
Industrialization of the Moon

Defining the Lunar Industrial Seed: What Comes Before How?

By David Dietzler pioneer137@yahoo.com © 2009

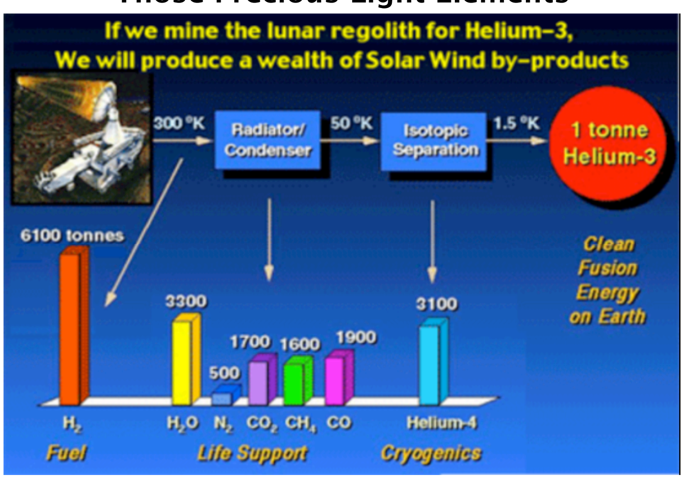
Part 2) Lunar Materials

The Moon: "Pie in the Sky!" But, oh, what a recipe!



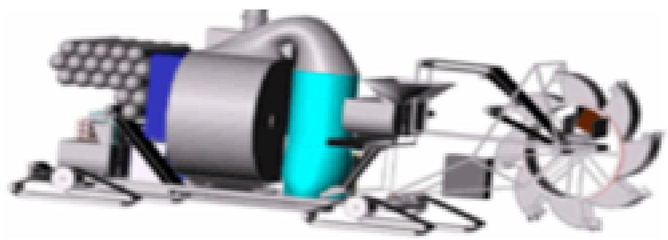
http://nsschapters.org/hub/pfd/MoonPieChart.pdf

Solar Wind Implanted Volatiles Those Precious Light Elements



Perhaps the first job to be tackled on the Moon will be mining for solar wind implanted volatiles–hydrogen, carbon, nitrogen and helium. These will be needed for life support and industrial processes. Mining robots will shovel up regolith, load it into onboard furnaces, and roast out the volatiles at about 700 C. Hydrogen will come off as is and some will react with oxygen in the silicates of the regolith to form H2O. Carbon will form CO, CO2 and CH4. Nitrogen is almost inert and will come of as is and so will helium, both helium 3 and normal helium 4. Hydrogen is needed for ilmenite reduction and CO and CO2 will be reacted with H2 over a nickel catalyst to form CH4 that can be decomposed with heat at about 900 C. to yield carbon and recover hydrogen. Carbon will be needed for life support systems when agriculture begins, steel and for carbonyls of iron and nickel for chemical vapor deposition processes. Until agriculture begins and closed ecological life support systems are at work, CO2 will be a nuisance removed from cabin air with physio-chemical systems and dried food will be upported and rehydrated with recycled water. Once CELSS is going, the top priority for carbon will be life support rather than industrial processes. Fortunately, industry won't demand much carbon since there are substitutes for steel and CVD won't require much either. Also, all carbon used for CVD will be strictly recycled. Nitrogen will have uses for CELSS. Helium can be used as an inert gas for work chambers where vacuum and oxidiation are undesirable and as a rocket fuel tank pressurant.

Storage and processing systems for these gases and water must be upported. Hydrogen can be stored in solid media and room temperature. Carbon monoxide, dioxide, methane and nitrogen can be liquefied with pressure and cooling. Helium must be cooled to near absolute zero so this element must be stored in high pressure gas tanks since it might not be practical to upport heavy multistage cooling equipment; however, if the helium is piped through shielded space radiators exposed only to the ten degrees Kelvin temperature of outer space, it might be possible to liquefy helium on the Moon without excessively heavy machines.



The Mark 3 miner designed at the University of Wisconsin, Madison, is projected to amass ten tons and could produce over 200 tons of hydrogen, 16.5 tons of nitrogen, 82 tons of carbon and about 100 tons of helium every year [1]. That's an incredible bounty from a ten ton machine, not counting the solar power systems needed to energize the machine, when it will cost thousands of dollars per pound of mass sent to the Moon. One of my associates has calculated that with the Apollo system it cost $30,000 to send a pound to the Moon. If the cost of upports drops to say $10,000 a pound with the success of rockets like the Space X Falcon 9 then we would still pay $4 billion to send 200 tons of H2 to the Moon. A pound of 1% carbon high grade steel for drill bits or milling heads would contain $100 worth of carbon. That's a high price for steel. Better to use lunar carbon for lunar steel. The value of mining for solar wind implanted volatiles on the Moon is clear.

One of the first jobs we should do on the Moon is mine for volatiles and stock up a supply of them pending later development on the Moon. This could be done with teleoperated robots years before a manned base is constructed.

That Essential Oxygen

Oxygen is necessary for breathing and producing water, but also for rockets. A reusable robotic Moon Shuttle might tank up with LOX on the lunar surface and rendesvouz with spacecraft arriving in LLO with just enough fuel for landing on the Moon. The Moon Shuttle carrying enough LOX for descent will dock with the cargo craft and take on fuel then descend to the lunar surface. This system will increase the amount of cargo that would otherwise consist of oxidizer upported from Earth to the Moon and reduce costs. If the system is reliable enough it could be used to land humans on the Moon too and supply LOX for return to Earth.

Fuel for the Moon Shuttle's ascent would have to be produced on the Moon. If one Mark 3 miner can produce 200+ tons of hydrogen a year, a small fleet of them could produce enough H2 for fueling Moon Shuttles as well as other purposes. It might be possible to stretch the hydrogen supply by combining it with lunar silicon to produce silane-SiH4. Naturally, we'd have to upport the silane making equipment. Keep in mind that oxygen is 6/7 to 8/9 of the propellant mass in a hydrogen/oxygen fueled rocket, depending on mixture, and 2/3 the propellant mass of a silane/oxygen fueled rocket.

Not only must we produce oxygen, but also storage tanks, piping systems, pumps and space radiators to liquefy oxygen. We will need a system for producing oxygen, probably molten silicate electrolysis or vapor pyrolysis. These systems could also produce silicon for making silane. . Lander tanks might be used for the first LOX storage tanks.

In the early years we will upport insulated LOX storage tanks and associated piping, compressors and space radiators. To make foil shielded space radiators exposed only to the ten degrees K. temperature of outer space we will need metals production on the Moon, and this will require upporting some small smelting furnaces and making some large furnaces on the Moon from cement, silica and/or titanium dioxide bricks.

Cast and Sintered Basalt - This simple and general purpose material can be made just by putting some mare regolith which is just hardened lava pulverized by eons of meteoric bombard-ment into a fine powder into a furnace and heating it up to 1250-1500 C. The molten regolith will be poured out into sand molds dug in the soil to cast bricks, blocks and slabs. To make sintered blocks we must put the Moon dust into trays to size the blocks and heat them up just enough to get the edges of the particles to fuse. This simple black glassy material, cast basalt, has been used for centuries to make pipes, tiles, blocks and even fine table ware. It is very hard and abrasion resistant.

Mobile robots could use microwaves to melt mare regolith as they roll over it to make roads after the stuff hardens that vehicles and robots could roll over without kicking up dust. Landing and launching pads could also be made this way. Entire areas surrounding Moon bases where manufacturing and construction are going on might be treated this way so that dust isn't kicked up by wheeled vehicles and robots.

Silicon and Iron - These can be produced by serial molten silicate electrolysis also called magma electrolysis [2]. In the same way that an electrical current can be passed through water to break it down into oxygen and hydrogen, a current can be passed through molten regolith to partially break it down into its constituent elements. This also yields oxygen and a ceramic that melts at about 1500 C. The ceramic might be used to build more magma electrolysis furnaces. Sodium, potassium, phosphorus and sulfur might be produced as impurities in the oxygen that could be filtered out in cold traps. Silicon will probably need purification in vacuum distillation furnaces and by zone refining before doping to make solar panels.

Iron could also be extracted from regolith where meteoric iron fines are present at up to 0.5% by weight. Low intensity magnetic separators and grinders to bust up the silicates adhering to the fines will be used [3]. This meteoric iron contains 5% nickel and 0.2% cobalt.

Iron might be combined with some upported or Moon mined carbon, preferrably Moon mined carbon, by using the old blister steel or cementation process to convert it to stronger steel. see:

http://www.moonminer.com/blister-steel.html

Titanium and Titanium Dioxide - The mineral ilmenite can be concentrated by magnetic and electrostatic processsing of mare regolith where it is about ten times more abundant than in highland regolith [4]. Ilmenite can be reduced to titanium dioxide and iron particles with hot hydrogen gas in a fluidized bed. Water forms and is condensed, electro-lyzed to recover hydrogen and gain oxygen. The fused TiO2 and iron particles can be sepa-rated by roasting in the vacuum or by treatment with CO gas to produce iron carbonyls. Titanium dioxide particles could be sintered to make a high temperature ceramic that melts at 1800 C. Since cast basalt (molten regolith) melts at 1250-1500 C., iron at 1200-1500 C., silicon at 1400 C. and silica at 1700 C., these materials could be melted in titanium dioxide lined furnaces. Titanium metal could be obtained by deoxdizing TiO2 in FFC cells filled with upported CaCl2 flux. The FFC process will also gene-rate oxygen. Sponge titanium from FFC cells would be melted with electron beams instead of arc furnaces and cast into into slabs, ingots and billets or atomized to get Ti powder without adverse reaction with hydrogen, nitrogen or oxygen in the free lunar vacuum.

Magnesium - It might be possible to concentrate magnesium bearing olivines and pyroxenes from mare regolith by magnetic and electrostatic means. These could be reduced to magnesium metal in furnaces with silicon from magma electrolysis and a calcium aluminate (CaAl2O4) flux at about 1500 C. The magnesium metal boils off and is condensed. If olivines and pyroxenes don't take to silicothermic reduction, then magnesium oxide obtained by roasting regolith at 1500 C. and hotter will be used. Silicothermic production of magnesium has now all but replaced magnesium chloride electrolysis.

Aluminum - Three processes stand out for aluminum production. All will involve concentration of anorthite by magnetic and electrostatic means.

A) 1) Sulfuric acid leaching of anorthite.
   2) Roasting aluminum sulfate to aluminum oxide
   3) Carbochlorination of Al2O3 4) Electrolysis of AlCl3 in a flux of lithium and sodium chloride [5].

B) 1) Direct carbochlorination of anorthite
   2) Distillation of AlCl3 and SiCl4
   3) Electrolysis as in step 4 above [6].

C) 1) Roasting anorthite at up to 2000 C. to get CaAl2O4
   2) Electrolysis in a lithium fluoride flux [7]

Process A will yield a lot of CaSO4 and silica by-product. If the CaSO4 is not useful, it can be decomposed with heat to recover sulfur. Process C seems simplest but it will require a very high temp. furnace, upported lithium fluoride since these two elements are lacking on the Moon, and special alloy electrodes. Carbon and chlorine will have to be carefully recycled. The only likely lunar source of chlorine is pyroclastic glass.

Cement

This all purpose material can be produced by roasting highland regolith at 1800-2000 K. to drive out SiO2 and enrich CaO content [8]. The SiO2 can be condensed and used for glass. Glass fiber reinforced concrete will be very strong. Typical Portland cement contains 5% CaSO4 to slow setting time. I don't know if this will be necessary for lunar cement but if aluminum process A above is used there will be plenty of CaSO4 available. Cured cement does not have to absorb CO2 to set as does lime and sand mortar and it contains about 5% water by wieght. Cement things could be cast in pressurized inflatables to recover H2O as it dries. Sulfur can also be used to make cement. Habitat modules made of concrete will be buried, thus not exposed to thermal extremes and will not expand and contract so much that they crack. With thick enough walls and glass fiber reinforcement they will stand up to internal air pressure well.

Glass

Glass is yielded by H2SO4 leaching, roasting regolith to get cement and by roasting regolith to get MgO. Molten glass can be drawn through dies to get glass fibers. These glass fibers can be mixed with molten glass that has been mixed with lunar sodium, potassium and perhaps even lead, if any from uranium decay on the Moon, to lower its melting point and the result is a glass-glass composite material. This material needs more study. It might even have Earthly applications.

Sulfur

Regolith contains c. 500 to 1700 ppm sulfur. To the best of my knowledge most of this is in the form of the meteroic mineral Troilite-FeS. This mineral could be extracted electrostatically from large masses of regolith by machines similar to the ones that mine for volatiles and iron fines. It could be decomposed with intense heat in a solar furnace to get sulfur and some iron too. Molten sulfur can be used instead of water to make cement. We might be more willing to sacrifice sulfur than water if we must cast large concrete objects out in the vacuum.

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The Lunar Industrial Seed, Cont.

Part 3A: Manufacturing

The "MUS" part of the Industrial Development MUS/cle Strategy*

* http://www.lunar-reclamation.org/papers/muscle_paper.htm

Massive, **U**nitary and **S**imple things that will be costly to upport but easy to make on the Moon due to their simplicity will be manufactured during the early stages of lunar base development lasting from several months to a few years. **C**omplex, **l**ightweight and **e**lectronic (or expensive) items will be upported until the base grows to a point at which large numbers of small to medium sized parts are needed.

Furnaces

Some of the heaviest pieces of equipment used on the Moon will be furnaces for refining regolith and minerals, melting metals for casting, making cement and melting glass for fibers and other uses. A 70 tons magma electrolysis furnace would use 3 MWe and produce about 1000 tons of oxygen, several hundred tons of silicon and iron, and over a thousand tons of ceramic in a years' time [1]. If the mass of the industrial seed is several hundred tons this will really make a dent in our mass budget. We will need to upport a much smaller furnace and use it to get some ceramic for constructing more furnaces as well as provide some oxygen, silicon and iron. The ceramic could flow out of the furnace and into sand molds to make blocks that are welded together with electron beams or microwaves to build another larger furnace. The platinum electrodes would have to be upported. There would also have to be systems for piping away and storing the oxygen and solar panels to energize the furnace.

Other furnaces could simply heat regolith or metals to melt them down and cast them into ingots or plates and slabs. Some furnaces will use electrical heating elements, probably upported in the early years, and others will use concentrated solar energy. Since some materials reflect light electric furnaces will be preferred to heat these. Solar furnaces will also need large Sun tracking reflector systems to collect enough energy to super heat materials. The use of titanium dioxide brick or block linings that are also e-beam or microwave welded together must be considered. The linings would not have to be thick enough to give structural strength to the furnace, but only thick enough to insulate the surrounding concrete that makes it sturdy enough to contain tons of molten materials.

Liquid Gas Storage

We will need to store liquefied CO, CO2, CH4 and N2 from volatiles mining. Hydrogen could be stored in solid hydrides or carbon nanotubes. Helium might require high pressure gas tanks. Since commercially pure titanium is strong enough for LOX storage systems, and is more corrosion resistant than stainless steel, it might be best to make the tanks out of titanium although titanium production is more complex than iron and steel production but less tricky than aluminum production. Some aluminum and tin to alloy the titanium might also be required.

Lander tanks might be used for the first LOX storage tanks. To make more tanks and accessories we will need to produce metals. The first metal to be produced on the Moon might be iron from magnetically extracted iron fines of meteoric origin that compose up to 0.5% of the regolith. This iron might be combined with some carbon, preferrably Moon mined carbon, by using the old blister steel or cementation process to convert it to stronger steel. The steel would probably be alloyed with nickel The tanks would be lowered into trenches where they rest on cast basalt supports. Cast basalt is a good thermal insulator. The trenches will be covered with foil solar shields. It should stay good and cold down in the trenches. Will heat radiation from the regolith at minus 4 F. be a problem? That's warmer than LOX at minus 183 C. The walls of the trench could be covered with shiny low heat emitting foil and the vacuum will insulate more.

Solar Panels Needed Early

Initially, power willl come from solar panels landed on the Moon. These might be GaInP/GaAs/Ge stretched lens array panels that get 300 w/kg to 500 w/kg and 300-400 w/sq.m.[2]. One metric ton of these could generate 300 kilowatts! More solar panels will have to be produced to replicate and grow the seed. We don't have exotic elements like gallium and indium on the Moon. Solar panels will require silicon, aluminum, phosphorus and glass. Some boron for doping p-type silicon and some phosphorus for n-type material could be upported and combined with silicon produced on the Moon to make more solar panels to power more equipment as needed.

Eventually we will have to produce aluminum on the Moon to make p-type silicon and produce phosphorus too, so we will need devices for producing Al and P on the Moon as well as devices for producing silicon. We will also need devices for rolling aluminum slabs or ingots into sheets for the solar panel backing, extruding them into wires and devices for producing aluminum mesh for the top electrode to make solar panels.

Certainly, the MUS/cle strategy is needed here because rolling mills will be very heavy. It might be possible to make aluminum sheets by depositing vaporized aluminum on glass plates in the vacuum. Glass will also be used to cover the panels. Robots to assemble the solar panels, deploy them and wire them up will also be necessary. All expansion of the lunar industrial seed will depend on electricity so it will be necessary to produce solar panels in large numbers within just a few years' time after the manned and robotic initial base is built.

Basic Bricks

Brick making will be essential. I envison solar or electric furnaces loaded with regolith and molten regolith pouring out into simple sand molds dug in the lunar surface to cast bricks, blocks and slabs. Hopefully, the molten material will cool off and solidify before too much evaporation into the vacuum occurs. Iron molds with silica linings might also be used to cast bricks as they will cool down faster in such molds than they would in sand molds. Bricks will be needed for interior walls, walkways, and retaining walls that hold up regolith over buried modules. Slabs will be needed for short roads that robots can roll over without kicking up dust near the equipment. Cast basalt or pressed and sintered basalt possibly with metallic reinforcements will be used to make bricks and slabs. Molten silicate electrolysis also produces a spinel and silicate rich ceramic in addition to iron, silicon and oxygen with impurities most probably sodium, potassium and phosphorus that could be condensed from the oxygen.* The ceramic will melt at around 1500 C. and might be very useful. See:

http://www.moonminer.com/Moon-bricks.html and
http://www.moonminer.com/Magma-process.html

Metal Plates

Metal ingots and slabs from simple sand molds will have to be rolled into plates and sheets. A rolling mill is a very heavy piece of equipment. Since aluminum and pure iron are softer than titanium, a rolling mill for these metals might be made of lunar titanium. While the electric motors will be upported at first, the titanium rollers and frame could be cast on the Moon. Graphite molds or copper molds with cooling passages, inert gas coolant and space radiators would be needed to cast titanium in the vacuum.

To roll steel and titanium plates we will need hard steel or cementite (Fe_3C) rollers. This would demand some carbon; even so, a 5000 pound rolling mill made of 1.5% carbon steel would only contain 75 pounds of carbon, so the sacrifice will not be great. I don't think we will be rolling steel plates on the Moon. We might be rolling titanium plates for pressurized vehicle cabins. It might also be possible to pour titanium plates _" to 1" thick in shallow molds made of TiO_2 that are covered with a slab of glass to prevent evaporation of metal into the vacuum. Metal plates will be welded up to make buckets for mining shovels as well as other things.

Contour Crafting

A promising method of manufacturing and construction with cement/concrete is called Contour Crafting. This is similar to 3D additive manufacturing but on a much larger scale. It might be possible to "print up" concrete buildings and other items. See:

http://www.contourcrafting.org

Cement will be needed for floors in chambers where molten metals are handled and cement or concrete cylinders several feet thick could be used for habitat modules. It can also be used to make cement board for walls, plumbing and furnishings. The lunar industrial seed must include solar or electric furnaces for cement making, sealed cement mixers and hoses, inflatables for working with cement in which we can recapture water vapor from drying cement items, and fuel cells for combining oxygen and hydrogen to make water as well as electricity.

To make plaster molds and sand molds, inflatable Kevlar work chambers filled with an inert gas will be needed. As the wetted plaster or sand dries precious water vapor will be recovered by dehumidifiers. The inflatable chambers will have concrete floors in case molten metal is spilled. The cement powder will be mixed with water in airtight devices and the wet cement will be pumped thru hoses into the chambers where it dries and the water vapor is recovered. Casting robots must work in pressurized chambers to prevent evaporation of molten metals in the vacuum also during casting operations. see:
http://www.moonminer.com/Casting_Chambers.html

Cement and concrete production will not involve any upported chemical reagents as will some metal production processes and the equipment needed to make it will be comparatively simple. If concrete is exposed to the intense thermal cycles of the Moon it might crack; however, pressurized habitat modules made of concrete will be buried and the sub-selene temperature just a few feet down is a constant minus four Fahrenheit. Concrete could be strengthened by mixing it with glass fibers made from the SiO2 that boils off when highland soil is roasted to make cement.

Extrusions

Extruders will be part of the lunar industrial seed. Rods, bars, rails, wires and pipes can be made by extrusion. Rods can be used for axles, bars for vehicle frames, rails for railways, wires and pipes for obvious uses. Lunar extruders will not use hydraulics. Their rams will be powered by electric motors and large screws or augers. It should also be possible to extrude hot soft glass or basalt into fibers for use as sound deadener, thermal insulation, concrete strengthener, and glass cloth. Special looms and sewing machines will be needed to make glass cloth items. Glass cloth will not be used for clothing because it is abrasive (although it might be coated with plastic-see:

www.asi.org/adb/02/16/01/01/glass-fiber-textiles.html

but it could be used for tents that protect equipment from the heat of mid-day, spacesuit outerwear, curtains, drapes, rugs, mildew resistant wallboard, insulation for electrical wires and runners that lunar workers can walk across out-vac without kicking up lots of Moon dust. It might also be possible to use glass cloth sealed with silicones to make inflatables on the Moon.

*Phosphorus is needed for n-type solar panel material. Along with potassium it is one of the three major fertilizer ingredients with nitrogen being the third. Potassium and sodium can be reacted with water to make potassium hydroxide and sodium hydroxide-caustics for soap making by mixing them with vegetable and/or animal fats. Soap will be an essential for humans on the Moon. Sodium is needed to make table salt, another essential for humans, and sodium hydroxide reacted with silica can make sodium silicate, an inorganic adhesive with many uses.

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About the Author

Dave Dietzler is a founding member of the St Louis Moon Society chapter and a major contributor to Moon Miners' Manifesto over the years, as well as the principal "co-braintormer" with the editor on many technical issues that pertain to the establishment of a viable lunar frontier.

What I Like about the Augustine Commission Recommendations for our Future Manned Space Program

By Tom Heidel

Yes, I have read a lot of the "Oh, woe is us" editorials and commentaries. I understand how long time supporters of NASA's exciting plans to return to the Moon feel. The rug has been pulled out from under them. But has it? Don't kill the messenger if you don't like the message! The single pertinent fact is that NASA's Moon program was underfunded from the gitgo, and, to that extent, a political ploy. Given the current economic times, it is unrealistic to expect that funding level to be increased substantially, much less left at the current level.

But I am not at all sure, that the recommendation that we fly manned missions to some asteroids and maybe even a manned flyby of Mars is a bad alternative. I have a plaque in my office that reads, *"the contented man is one who enjoys the scenery along the detours."* This alternate plan for manned space activities may seem like a detour. But is it?

First, the rockets and other equipment to support such missions will be ready sooner, so we will get to visit some neat places in the interim. Meanwhile, with NASA detoured from the Moon, the agency may be able to pull off a badly needed "attitude adjustment" to collaboration with other national space agencies.

A NASA only Moonbase effort would be much less robust than one mounted by the **Lunar Infrastructure Development Corporation** proposed by Buzz Aldrin. [p. 9, below] NASA could join a more robust international effort with multinational corporations as partners as well, at much less expense than would be incurred by carrying the current sometimes-occupied not-fully-functional "shelter" it has been planning.

And it would not surprise me that such an international beachhead could become fully functional before NASA's first Altair lander would have killed its descent engines. There is a time for national pride and there is a time for getting the job done right. And that means establishment of an industrial resource-using beachhead on the Moon in a location where all the Moon's resources can be tapped, not just a sexy subset.

What asteroid(s) would a NASA manned crew visit? What science could be done in a mere flyby? What would be gained in sending men around Mars without landing? We've got some suggestions, but NASA will come up with its own, so ours don't matter. Meanwhile, *NASA will be doing something,* and in the meantime, the alternative International lunar effort, one that could be much more robust, would be taking shape.

I think these "sideshow missions" could be very interesting. And I plan to enjoy the scenery along these detours. Meanwhile, NASA's Moon plans, without enough money to do in robust fashion, were really much ado about nothing. Sometimes we need a setback to get ourselves on a more secure path forward.

The Moon belongs to all of Earth. Humans will get there, and stay, and our world will have cloned itself. Too many chefs? Well, I am looking forward to tasting the soup! **<TH>**

Antarctica's McMurdo Station:
A Preview of Growth & Expansion of A First Lunar Industrial Settlement?

By Peter Kokh kokhmmm@aol.com

The maze of McMurdo Sound Station from above:
A harbor, 3 airfields, a heliport and over 100 buildings

With a summertime population of 1,300, this outpost is a functioning city. The only difference with conventional cities is that its population consists of only temporary residents: no families making the continent their home. But that is another story. The Antarctic Treaty discourages settlement, private property, and development of local resources to support a viable economy. Those provisions are a powerful reason not to look to the Antarctic Treaty as a model to apply to the Moon.

McMurdo is about 55 years old and its growth to its present state has been steady, driven by the ongoing expansion of the research programs supported there. Is there a pattern to that growth that suggests how an outpost on the Moon could morph into a settlement over time? From one angle the answer is a resounding "no!" We would expect a lunar outpost's growth to be acceleratied by a steady shift in reliance on imports to basing growth on locally produced materials and goods. That would be reflected in the appearance of added structures and their furnishings trending toward a definite made on luna look and feel. A lunar outpost would sink roots as it grows. McMurdo's growth is supported by an insatiable appetite for ever more imported supplies. This pride of Antarctica would die a cold death in a minute were the supply chain cut. In the battle to keep supplies flowing, icebreakers and cold-hardy cargo planes are the workhorses.

Nor does McMurdo produce any goods or exports other than knowledge and reports of real interest but of no economic value. As big as the outpost has grown, it has made no progress towards self-reliance or economic viability. Again, not a model to be inspired by.

Science is the reason McMurdo exists but the scientists are outnumbered by providers of support for operations, logistics, information technology, construction, and maintenance.

After a visiting Greenpeace ship documented haphazard littering and apparent lack of appreciation for the host environment, the outpost was forced to cleanup and rethink the way it expands and the way it deals with discarded and used items. This catharsis has been all for the good. Waste not, want not. But this is a lesson a lot of are learning in cities and towns wherever we live.

We have pointed out that for a lunar outpost, a prior plan for warehousing incoming supplies as well as replaced items, together with a plan for site management and planned vectors of growth are essential if the outpost complex is to grow in an orderly and efficient manner. Historically, most towns and cities have grown by one "afterthought" after another. Planned growth need not mean cookie cutter replications. Variety, inventive-ness and individuality are what make towns attractive.

McMurdo is Antarctica's principle hub, both for supplies coming by sea and for those arriving by air. A sector of the population is occupied entirely by these logistic activities. But it is also a departure point for many overland exploratory excursions. If McMurdo did not exist, we'd have to invent something quite similar.

There is no manufacturing district, no farmers market, no schools for children. A city it may be, but a parody of what we mean by city nonetheless.

If a lunar outpost is to focus on weaning itself of total dependence on imports from Earth, it must grow industries and enterprises and farms and trade partners. In this sense, the smallest African village is perhaps a better model of growth to follow than is McMurdo.

Most of the growing tourist trade to the continent skirts its perimeter, exploring off-shore islands along the Antarctic Peninsula below the tip of South America. McMurdo is half an Earth-turn away, below the tip of New Zealand. Tourists are not encouraged. If you want to go, join the Navy, become a scientist, or find employment with one of the station servicing suppliers.

Albert P. Crary Science and Engineering Center, 1991

Many space enthusiasts look for the day when we have something similar on the Moon. Yes, humans would be there in force. But no, this would not be a genuine human settlement paying its own way with a mix of industry, agriculture, and trade, growing its own work force family-style rather than by temporary assignment. McMurdo's growth drivers and growth vectors are not the natural ones of real cities. It will never be "home" to anyone, just a place to pretend is home. Despite its location on a previously uninhabited continent-world, it is not a model for lunar settlement developing local resources to become economically independent. **PK**